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SOIL HORIZON DESIGNATIONS

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TABLE OF CONTENTS

List of Tables

List of Figures

PREFACE

Since the time of Dokuchaev, soil has been regarded as an *"independent natural body"* and worthy of study in its own right. Soil Scientists have found general agreement in the concept of soil as a three-dimensional body being composed of mineral and organic matter which has been formed by various environmental factors into a soil profile composed of a number of horizons. However, there have been may divergent opinions about the interpretation of the genesis of the soil profile and the significance of its morphology. Soil horizon designations, the subject of this monograph, have been a controversial element in soil science ever since their inception over a century ago. It is possible to trace a sequence of development from simple labelling, through a genetic phase, to a morphological phase and finally to what is here referred to as a prescribed phase of soil horizon designation. With the development of new systems of classification using the concept of the diagnostic horizon, it seemed that the usefulness of the soil horizon designation was passing. However, this may not be so.

In an amusing poem *"A Lament for B"*, Kellogg[1] mourns the passing of the earlier form of soil horizon designations in the genetic ABC system:

The death of mother B
Marks the end of royalty
How can we maintain distinction
Midst so much discrimination

In spite of an increasing dependence upon laboratory criteria for the purposes of classification, the study of soils is essentially based on field studies, relying upon accurate observation and intelligent appraisal of soil morphology.

Can we take the lab to see
All soil morphology?
Or do we add to field condition
Genetic truth from relevation?

This monograph searches through the knowledge of the past and present, and attempts to look for some future trends in the development and use of soil horizon designations. It was prepared in two stages, the first version being a Working paper of ISRIC which was circularised to Soil Survey Organisations and to interested individuals. The second stage involved the incorporation of the constructive comments received into the text of this monograph. The response of soil survey organisations is listed in Chapter 5, and individual correspondents who responded to letters of enquiry are thanked in the acknowledgements.

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[1]C.E. Kellogg, 1987. 'A Lament for B'. Limited Edition, Twelve Oaks Press, Portland , Oregon, USA.

The aim of this monograph, and the working paper which preceded it, is to assemble a body of information which may be used as a basis for discussion and improvement of the methodology and use of soil horizon designations. Hopefully, this monograph will encourage the free interchange of information about soil horizon designations, and encourage rational discussion of the problems surrounding its use. It is emphasised clearly from the outset that there is no intention of trying to inhibit any individual or national initiatives, but the widespread use of some form of horizon designation does seem to indicate the need for adopting a more uniform approach in the designation of soil horizons.

The objectives which it is hoped this monograph achieves are as follows:

1. To present a discussion document containing the constructive comments received on the subject of soil horizon designations. This has been achieved by the following steps:
   a. By tracing the historical development of systems of soil horizon designation from their inception to the present day.
   b. By gathering information about systems of horizon designation currently used by soil scientists throughout the world.
   c. By ascertaining where there are areas of agreement or disagreement in the use of soil horizon designations.
2. To examine the possibility of developing further a unified system of horizon designation, based on current working practices.
3. To examine the possibilities of using or developing an alternative approach to the present soil horizon designations.
4. To prepare a bibliographic list of books and articles relevent to the subject of soil horizon designations, and to deposit this information in the ISRIC library where it is accessible for any persons who may be interested in the further study and development of the subject.

ISRIC, Wageningen. 30 April, 1989 E.M. Bridges.

INTRODUCTION

Soil horizon designations have served a very useful purpose during the past century since Dokuchaev first labelled the visible layers of soils with the first three letters of the Latin alphabet. However, there is considerable divergence of opinion about the use of these symbols. Some pedologists are content to use horizon designations, usually based upon the FAO Guidelines, with local modifications where necessary; other pedologists avoid their use altogether claiming that they introduce an undesirable subjective element into the description of soil profiles.

The basis of soil study by pedologists in virtually all countries of the world is a soil volume, represented by a soil profile with its constituent horizons and layers. Ideally, this soil volume should be of sufficient size to encompass the nature of the horizons and any variability present. Such a volume of soil has been called a pedon (Soil Survey Staff, 1975) soil area (Muir, 1969) or pedounit (FitzPatrick, 1980). Different authorities specify different sized areas; these lie between 1 and 10 m^2 but Avery (1980) acknowledges that for practical purposes, this frequently becomes 1 to $2m^2$, the area of a typical soil pit. The lower boundary of a soil and material which is not soil is left "somewhat vague" (Soil Survey Staff, 1975). This lower limit has been described as "the deeper of either the unconsolidated mineral or organic matter lying within the zone of rooting of the native perennial plants; or where horizons impervious to roots have developed, the upper few feet of the earth's crust having properties differing from the underlying rock material" (Soil Survey Staff, 1960).

The soil profile results from the dynamic interaction of one or more soil forming processes in which chemical, physical and biological activities are combined. The effect of these processes is to produce the sequence of horizons which comprises the soil profile. The character and arrangement of these horizons within the profile provide the morphological information which is the basis for distinguishing one soil from another and which enables soils to be classified and mapped.

To be able to recognise the succession of horizons in a soil profile and to identify a soil in the field is a fundamental skill which all pedologists must acquire, and is highly desirable in practitioners of all other branches of soil science. Although the succession of horizons in a profile does not have to be labelled, the usefulness of the description is greatly enhanced by the proper use of horizon designations as these add the investigator's interpretation of soil genesis to the bare bones of the soil morphology. So, the system of soil horizon designations in all its various forms has evolved with pedological studies as an aid to identification and discussion of the features of soil profiles.

Variation in detail amongst the many systems of horizon designations in use throughout the world is confusing and this makes them less useful than they might otherwise be. This problem has been recognised in the past by the International Society of Soil Science and by the Food and Agriculture Organisation of the United Nations. Since the use of soil horizon nomenclature was reviewed by these organisations in the 1960s and 1970s respectively, there have been many new proposals notably from Australia, Canada, New Zealand, United Kingdom, USA, USSR and West Germany. It was thought a review of the situation was desirable and ISRIC the appropriate organisation within which the review should take place.

The subject of this report is the representation of soil horizons by symbols (referred to as soil horizon designations or soil horizon notations) formed from a combination of letters and numbers. Consequently, the definition of diagnostic horizons will only be dealt with in-so-far as it is relevant to the subject of soil horizon designation. As soil horizons are the key to many, if not all aspects of soil science, and particularly of pedology, their identification and designation is an important feature of the discipline. Marbut (1922) listed ten criteria concerning the differentiation of soils at the level of the soil type. Nine of these criteria were concerned with the number, arrangement, thickness, colour, texture, structure, and composition of horizons of the soil profile, the tenth referred to the parent material. Although many innovations have been made and new concepts developed since Marbut's time, his appraisal of the importance of soil horizons remains valid today. The concept of the soil horizon is fundamental to pedological studies and central to the understanding of soil genesis. A soil horizon designation may be described as:

> **an interpretative symbol, based upon horizon morphology and implied genesis that is used to identify and label a soil horizon.**

The development of any scientific subject is marked by definition and re-definition of its subject matter and soil science is no exception. Some of the accepted definitions in use at the time of the First International Congress of Soil Science at Washington are given by Shaw (1928). He defined the soil profile as "a vertical section of the soil from the surface to the underlying unweathered material". A soil horizon was defined as "a layer or section of the soil profile, more or less well defined, and occupying a position approximately parallel to the soil surface". He makes the point that there are situations where "transported soils" result in layers that may have bearing on the character of the soil and gives brief definitions of the A, B and C horizons.

Before proceeding to a study of soil horizon designations, it is desirable to establish some present-day definitions for soil, the soil profile, soil horizons and soil layers which are found acceptable by most soil scientists. These are as follows:

Soil The collection of natural bodies, formed at the earth's surface from a variable mixture of mineral and organic materials, under the influence of the soil forming factors. These factors act through chemical, physical and biological processes to produce pedological features identifiable in the soil profile. Soil is the altered upper part of the regolith which provides support, nutrients and moisture for plants and therefore is a fundamental basis of life on earth.

Soil profile A soil profile includes the collection of natural layers of the soil as revealed in a vertical section from the organic material at the surface, through the horizons of the mineral soil to the parent material or other layers beneath which influence the genesis and behaviour of the soil. As the soil profile is an expression of only two dimensions of the soil body, pedologists prefer to use a three dimensional body of soil referred to as a pedon or pedounit.

Soil horizon A layer of soil, revealed in a soil profile lying approximately parallel to the earth's surface, having pedological characteristics. Horizons are the vertical expression of a volume of soil which can be distinguished from other horizons by morphology, physical make-up, chemical properties and composition and biological characteristics. The vertical and horizontal limits of soil horizons occur where these attributes undergo significant change in appearance or amount.

Genetic horizon A soil horizon with properties which identify it as having been exposed to a particular process or group of soil forming processes. For example, the basic concept of an A horizon is that it lies at the soil surface (unless buried) and it results from the long-term accumulation of organic matter but leaching of many other constituents. However, it may exhibit subsidiary features such as reducing conditions in areas of poor drainage or the accumulation of salts in arid regions; an E horizon is produced by the mobilisation and removal of iron oxides together with the destruction and removal of clay minerals leaving bleached sand grains; the B horizon results from changes *in situ* or from illuvial additions from the horizons above and may also be in receipt of material from soils in an upslope position.

Diagnostic horizons Named soil horizons that have a set of quantitatively defined properties which are used for identifying soil units within classification systems. Diagnostic horizons are distinct from genetic horizons in that their thickness and degree of development is stipulated. They may be surface (epipedons) or subsurface horizons. For example, an epipedon may include genetic horizons designated A and E and even the upper part of the B horizon (Soil Survey Staff, 1975). No official definition of a diagnostic horizon has been given by the authors of *Soil Taxonomy*, nor has it been explained how the limited number of diagnostic horizons were decided upon.

Reference horizons Soil horizons defined by a limited number of parameters created on co-ordinate principles which fall within a conceptual reference segment of the whole population of soils, possessing a unique dominating property or combination of properties (FitzPatrick, 1988a).

Intergrade horizons These are soil horizons which possess properties which fall within the zone of gradation between reference segments of the whole population of soils (FitzPatrick, 1988a).

Compound horizons These contain a combination of properties of two or more reference segments of the whole population of soils. These properties are usually contrasting and develop as a result of either seasonal processes or they have one set of properties superimposed on an earlier set (FitzPatrick, 1988a).

Composite horizons These horizons contain discrete volumes of two or more reference segments (FitzPatrick, 1988a).

Soil layers 1 Materials which occur at or near the earth's surface which are present as layers, more or less parallel to the soil surface which have resulted from biological or geological processes, not soil-forming processes. The organic materials are commonly referred to as layers, as are layers of aeolian, fluvial or solifluction mineral material in which the soil profile may have formed. Such layers often form lithological discontinuities which may persist and influence the process of soil formation.

Soil layers 2 Traditional names given to horizons or groups of horizons such as topsoil and subsoil also must be considered as layers. Use of the terms horizon and layer as defined are technical, whereas topsoil and subsoil are purely non-technical, descriptive layman's terms.

THE USE OF SOIL HORIZON DESIGNATIONS

Discussion and communication

The description of a soil profile with its component horizons should be an objective, factual record of the soil profile as it appears in an exposure or soil pit. Most soil survey organisations have evolved systematic methods of description which assist the surveyor and achieve a comprehensive account of the features of each horizon present.

It is not necessary to label each soil horizon to make a good description, and this is stressed in many soil survey field handbooks. Simple numbering systems or other undefined labels are useful for ordering horizon descriptions and particularly any samples taken from the profile. However, they give little information about the relationships between a horizon and its neighbours above or below it in the soil profile. As expressed in the USDA *Soil Survey Manual* (Soil Survey Staff, 1951):

> one cannot usefully compare arbitrary defined 12-24 inch layers of soil but B horizons can be usefully compared.

In this sense the purpose of attaching a horizon designation is clear and simple in operation; it facilitates discussion and communication of ideas. Despite the significance of the soil profile and its constituent horizons, samples are frequently taken from standard depths in commercial soil surveys where a rapid programme of sampling, probably by non-pedologist staff, is undertaken.

Interpretation

The designation given to a specific horizon of a soil profile results from the soil surveyor's interpretation of the intrinsic properties of that horizon. To establish the genesis of a horizon the surveyor must take into consideration the relationship of the horizons above and below. This is a deductive exercise in which the experience of the soil scientist and the evidence of the profile morphology are combined. The surveyor describing the profile is the only person who has all this information in front of him and he is obviously the one best suited to make any genetic interpretations.

Critics of the genetic system of soil horizon designations object to the use of adjacent horizons for the identification of a specific horizon, claiming that each horizon should be identified by its own unique properties. In fact it is very difficult to be completely objective as soil description is based on the interpreted morphology of the soil profile.

Classification

Kubiena (1953) utilised the sequence of horizons in the soil profile as a basis for soil classification, and subsequently several systems of classification also have used the concept of increasingly complex development of the soil profile in their structure. However, the genetic horizons and their designations are neither an alternative nor a substitute for the quantitative diagnostic horizons established in many contemporary classification systems. It cannot be stressed strongly enough that horizon designations are a subjective assessment by the field pedologist of the nature of the horizon and the genesis of the profile. The diagnostic horizons which form the foundation of many modern systems of classification rest heavily upon morphometry of soil horizons, stressing their thickness and their degree of development. An additional, practical reason for designating soil horizons at the time of profile description in the field is that the interval between field work and the completion of laboratory analyses may be measured in months or even years. After a long time interval, matching analytical results with field descriptions may be difficult, but with the intelligent use of horizon designations the task is made easier.

Objections to the use of soil horizon designations

Many individual soil scientists and some soil survey organisations have expressed misgivings about horizon designations as they are currently employed in pedology. It is claimed that the ABC system is not universally applicable, that it introduces a subjective element into profile description, it does not take into account changes in the impact of soil forming conditions and processes, it does not effectively describe intergrade situations and that there is considerable muddle over symbols used to modify the meaning and concepts of the master horizons. Despite all these disadvantages, the soil horizon designation continues to be used and developed, so perhaps it is worth examining some of these objections.

Lack of universal applicability

This is the most fundamental of the objections to the use of soil horizon designations and the one most easily appreciated. As will be described in Chapter 3, the ABC system originated and was developed upon the plainlands of the northern hemisphere in Russia and the United States. In these regions, soil development has occurred over a limited span of time since the end of the Pleistocene, often in glacial or aeolian parent materials, to give profiles which have a depth of a metre and a half at the most. It is assumed that soil horizons develop uniformly and parallel to the soil surface, but in many cases they do not. Many soil horizons are found to have a limited extent laterally and vertical tonguing of one horizon vertically into a lower one commonly occurs. Situations such as these produce complications which are difficult to resolve.

In many tropical soils, weathering has produced an extremely deep regolith and soil formation has developed a soil in its surface layers. The ABC system of horizon designations developed on the younger, shallower soils of the temperate regions becomes less successful when applied to the strongly weathered, deep soils of the old tropical land surfaces where creep and bioturbation have been active for a much greater length of time. In many soils, these processes result in layers which have been attributed to the action of gravity on slopes or the activity of soil fauna, rather than to the effects of the commonly identified soil forming processes.

The ABC system was developed for soils which were formed almost entirely by one special set of soil forming conditions. Although it is known that earlier climatic conditions were different from those at the present time, the imprint of the current soil forming conditions on the relatively shallow profiles of the mid-continental grasslands and coniferous forests was such that earlier features were insignificant and could be ignored. Since the 1950s though, many examples have been published of soils formed by successive periods of soil formation, each superimposing its effects on its predecessors. In these situations the use of the ABC system becomes difficult to apply as the genesis is often complex or unknown.

Problems arise also in soils where a mode of formation different from the leached profile occurs. Essentially the ABC nomenclature implies soil formation from the surface of the soil downwards; not all soil forming processes work in this manner. Where the process of gleying occurs, soils have oxidation-reduction processes taking place in lower horizons *in situ* and movement of soil constituents in solution or suspension may be upwards or in a lateral direction, rather than downwards through the soil profile. With gley soils there is an additional problem that features of gleying may relate to a former stage of soil formation, rather than to the present one.

Where salts are present the processes of soil formation may well be different from the so-called 'normal' situation. In some cases, salts are blown in as particles or as aerosols which fall onto the soil surface and are washed down into the profile. The ABC nomenclature is not too difficult to apply in this case; however when the salts are brought into the soil profile upwards from the ground water and deposited within the profile by evaporation from an ascending water movement, the concepts of eluvial A and illuvial B horizons of the soil are not applicable.

The application of the ABC system is particularly difficult where organic soils are concerned. These soils, essentially formed of layers of organic debris, are normally saturated with water and there are few of the features present which are taken into consideration when defining horizons in mineral soils. In addition, organic soils may be drained and cultivated or some have thin mineral layers overlying organic materials. Although the special symbols O and H have been used for freely drained and saturated materials respectively, the horizon designations are little advance over a simple numbering of the layers present. The subdivision by degree of organic breakdown has been introduced (Soil Survey Staff, 1975). This has been widely accepted and logically follows the system used in mineral horizons.

It has been appreciated for many years that certain soils expand and contract strongly as they pass through wetting and drying cycles. Vertisols in particular exhibit mulching effects on the surface and heaving at depth in the subsoil which combine to produce the effects known as gilgai as well as the deep cracking observed in other types of clay soils. The physical disturbance of the soil inhibits development of horizons parallel to the soil surface and so it is difficult to apply the ABC nomenclature. Instead of the usual criteria for the identification of soil horizons, attempts have been made to define the horizons of vertisols on structure alone, rather than on features common to all soils.

Soils developed in the tundra regions of the world similarly are subject to heaving and disruption, leading to patterned ground with stone stripes and circles in coarse materials and polygonal structures in finer-grained materials. These strongly-formed physical features are unlike the roughly horizontal horizons of mid-latitude soils which makes the ABC horizon designations difficult to apply.

Many soils, particularly of the alluvial areas of the world, have developed on layered parent materials, other soils have developed on volcanic ash layers, loess or colluvial deposits. In many cases, these layers have been at the surface for sufficient time to allow a soil to form before they were covered. Studies of palaeosols have drawn attention to the superimposition of the soil profile upon layered soil materials (Yaalon, 1971). The problems become even more confusing when later stages of soil formation are imposed onto profiles from earlier periods of soil formation which have only shallowly been buried (Bos and Sevink, 1975).

Subjectivity and objectivity

Many of the problems mentioned previously result because the soil horizon designations have come to imply that certain ill-defined processes of soil formation take place to produce the horizons present in a soil profile. The evidence available suggests that Dokuchaev and Sibirtzev first labelled soil horizons with the sole object of identifying them but the genetic concepts subsequently introduced an element of speculation and subjectivity which is at variance with the objective field description of soils.

When making a soil profile description, the soil surveyor should describe clearly each horizon or layer comprising the soil profile. This description should be completely objective for "objective descriptions are the basic stuff of soil classification" (Soil Survey Staff, 1975). It should be a detailed account of factual evidence observed in the soil profile, regardless of its presumed genesis. Virtually all handbooks or guidelines for soil description stress this point, stating that it is not absolutely necessary to label the horizons of a soil profile to make a good description. However, it is maintained that objectivity can be retained by the use of the morphological results of the processes of soil formation, and not by the processes themselves. When expressed quantitatively, these features have an objective identification value.

A simple number or cipher only records a horizon sequence without genetic implications and so conveys little additional information. It has been suggested that all horizons should be referred to as 'layers' in the field and only when the laboratory studies have confirmed the field description, should the full genetic horizon designations be applied (Clarke and Beckett, 1974). However, when all the finer points about objectivity and subjectivity have been made, it is the soil surveyor in the field, with the soil profile exposed before him, who is in the best position to speculate about the genesis of the horizons and the development of the soil profile. Consequently, it is stated in *Soil Taxonomy* that "the usefulness of profile descriptions is greatly increased by the proper use of genetic designations", sentiments to which few soil scientists would object.

Critics of the systems of soil horizon designation currently widely used in pedological work affirm that it is necessary to develop an objective, strictly defined, code of practice for the recognition, description and classification of soil horizons (and eventually soils themselves). One of the aims of this monograph is to assemble background material so that rational decisions may be made for the future use of such systems.

RECOGNITION OF SOIL HORIZONS

A soil horizon is recognised from other horizons above and below by characteristics which can be observed or may be measured *in the field* . The criteria normally used are organic matter content, colour, texture, structure, consistence. Other characteristics which may be used include the presence of cutans, cementation, stoniness, pans, carbonates and soluble salts, artifacts, biological features, roots and pH value. The nature of the boundaries between horizons is described in terms of their clarity, depth and thickness. When all these characters are considered, it is claimed that horizons may be identified by their individual morphology and by properties which differ from those of the overlying and underlying horizons.

Although it is normally possible to recognise a horizon correctly at the time of profile description, there are occasions when the field criteria are insufficiently clear and recourse has to be made to laboratory analysis and micromorphological examination. In such cases, the field identification of the horizon must be provisional and confirmation of the correct designation has to await the arrival of the laboratory results.

Further consideration of the criteria used in soil horizon recognition follows but for greater detail the reader is referred to Hodgson (1978), to an appropriate soil survey field handbook or Vogel (1986).

Depth and thickness of soil horizons

After selection of the site at which a soil profile pit is to be dug, and the profile has been revealed, the next significant task for the pedologist is to identify the horizons present in the face of the profile. An experienced surveyor will describe a sufficient number of soil horizons to enable the profile to be described accurately; too many narrow soil horizons should be avoided as this adds unnecessarily to the complexity and length of the soil profile description.

The boundaries between soil horizons are not always as clear as the textbook examples imply. Here the experience of the surveyor is an important element in the interpretation of the profile. The properties of colour, texture, structure, consistence, etc. are all important in the recognition of the horizons and their boundaries. Usually, boundaries of soil horizons are described according to their depth, distinctness, form and thickness.

Depth The depth of horizons is normally measured from the upper surface of the mineral soil downwards for the mineral soil horizons and upwards for the superficial organic horizons. The depth of the upper and lower surface of each horizon should be measured and recorded, and where irregularities occur, the range of depths encountered should be noted. A typical entry may be: 28 (25-31) cm to 45 (43-47) cm.

Distinctness Where horizon boundaries are obvious, there are few difficulties in their identification, but in some cases they may be very gradual or indistinct. Although there has been considerable variation in definition of the terms used, most countries have adopted the wording of the 1951 *Soil Survey Manual* (Soil Survey Staff, 1951) which was reproduced and metricated in the *Guidelines for Soil Profile Description* (FAO, 1977): abrupt 20 mm, clear 20-50 mm, gradual 50-120 mm and diffuse 120 mm.

Form According to the definition, soil horizons occur approximately parallel to the soil surface but there is considerable divergence from this ideal situation as in some soils one horizon may be observed to tongue into a lower horizon. As in the case of distinctness of boundaries, most soil survey organisations have adopted a description of form close to that of the 1951 US *Soil Survey Manual* and the 1977 FAO *Guidelines for Soil Profile Description* . These are: smooth, if nearly planar; wavy if pockets are wider than their depth; irregular, if pockets are deeper than their width; and broken, if the horizon is discontinuous (Fig. 1).

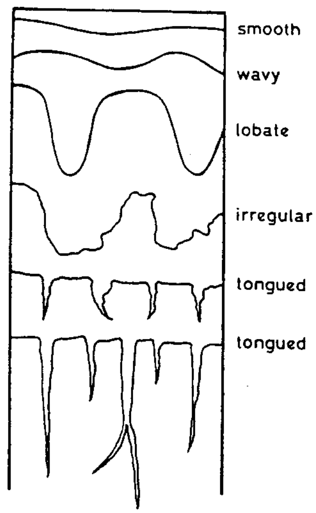

Fig. 1 Outline of horizon boundaries (FitzPatrick, 1980).

Thickness A thickness qualification is included in the current definition of many soil horizons, particularly the diagnostic horizons briefly considered in Chapter 4. Earlier approaches to soil description and classification were not as quantitatively orientated, and although thickness was measured, as a feature of classification it was not critical.

As an example, organic materials, or peaty surface horizons, must be more than 40 cm to meet the criteria for Histosols in the FAO-Unesco 1974 *Soil Map of* *the World* legend. Other horizons, such as the argillic B horizon (an appropriate clay increase within 30 cm), spodic B horizon (below 12.5 cm depth, or when present below an Ap horizon, a continuously cemented subhorizon more than 2.5 cm thick) oxic B horizon (more than 30 cm thick), calcic and gypsic horizons (15 cm or more thick) must all meet thickness criteria. Other national and international classification systems also adopt thickness thresholds for soil horizons.

Organic Matter

Soils comprise four basic constituents; mineral matter, organic matter, air and water. The organic matter component is derived from the plants and animals which live on and in the soil. The importance of biological activity in the soil is such that some authorities claim that soils result almost entirely from the activities of the soil fauna. The bulk of organic matter added to the soil is derived from plant material which arrives either as litter at the surface or as decaying roots within mineral soils. The plant material is a source of food and energy for the soil-living fauna which physically break it down and chemically decompose it until only humus, a complex ligno-protein, remains. Incorporation of organic matter into soils is largely the result of faunal activity such as earthworms taking plant debris into their burrows. Ingestion of plant remains results in a close association of mineral and organic compounds in their casts. Larger animals, such as moles, mix the organic debris with the mineral soil. Organic matter darkens the soil colour, confers stability to soil structures and increases the cation exchange capacity and in many cases can lead to increased natural fertility.

In general, soil survey organisations distinguish between horizons (soils) which are completely organic from those which are an organo-mineral mixture. Continually saturated organic materials are also distinguished from superficial organic layers which are only saturated for short periods of time. This separation effectively makes the distinction between peats and the thin organic materials referred to as litter, fermentation and humus layers. The FAO *Guidelines* (1977) recommend a lower limit of 30 per cent or more of organic matter (20 per cent if there is no clay in the underlying mineral soil, and proportional amounts for intermediate clay contents) for H horizons where prolonged saturation occurs. O horizons where complete saturation only occurs only occasionally are defined by a content of 35 per cent or more of organic matter.

The US *Soil Taxonomy* (Soil Survey Staff, 1975) has adopted similar standards defining organic soil materials as being either:

1. saturated for long periods or are artificially drained and excluding live roots, (a) have 18% or more organic carbon if the mineral fraction is 60% or more clay, (b) 12% or more organic carbon if the mineral fraction has no clay, or (c) have a proportional amount of organic carbon between 12 and 18% if the clay content of the mineral fraction is between zero and 60%; or

2. are never saturated with water for more than a few days and have 20% or more organic carbon.

With only minor variations to the above general criteria, Brazil, Canada, France, Germany, FAO-Unesco, ISSS Committee, Switzerland, UK, USA and USSR have all adopted similar criteria for the distinction between organic and mineral materials.

Muller (1879, 1884) is usually accorded the honour of being the first to name the forms of humus present in soils and Hesselman (1926) introduced the symbols L, F and H. Kubiena (1953) applied the technique of microscopy to their study and extended their descriptions especially of their micromorphology. The use of the terms mull, mull-like-moder and mor for forms of organic layers has tended to decline in recent years, largely because their definition was assessed in a subjective manner. However, they are still referred to in the literature and composite definitions are as follows:

mull formed beneath a vegetation, the litter of which is palatable to soil-living organisms. A mixture of mineral soil particles and organic material is ingested by the soil fauna and their excrement is an intimate mixture of the mineral matter and amorphous humus rich in bacteria. It is only slightly acid (pH 5.5) and is best developed in base-rich soils beneath deciduous trees which provide a base-rich litter.

mor formed beneath a vegetation, the litter of which is unpalatable to soil-living organisms. It is commonly found overlying freely-drained, acid, infertile soils on heathlands. The F layer is thick because of slow decomposition and slow mineralisation. A similar thickness of H layer abruptly overlies the surface mineral horizon.

moder an intermediate humus form in which the organic debris has rootlets, fungal hyphae and contains many faunal droppings. Fragmented plant material is browned but still recognisable and with depth it becomes comminuted until all resemblance with the original plant material disappears. A thin H layer occurs above the mineral soil.

Heiberg and Chandler (1941) divided forest humus layers into two main groups: mull and mor. Within the mull grouping coarse, medium, fine, firm and twin mull were recognised; the mor group included matted, laminated, granular, greasy and fibrous mor. Wilde (1965; 1970) identified ectorganic layers which rest upon the surface of the mineral soil and endorganic layers which form an intimate mixture of humus with the surface layers of mineral soils. Barratt (1964; 1969) makes a strong plea that the humus form should be recognised from the whole profile and not just from the superficial organic layers. Using field and micromorphological studies she identified sixteen humus forms associated with grasslands. These are: strongly granular, weakly granular, massive or blocky, fine, laminated, and lenticular mulls, and laminated mor-like mulls, and granular, massive, matted, laminated, banded and mullised mors. Full descriptions of these profile forms and of the associated micro-fabrics are given.

Babel (1971) defined the humus profile as that part of the soil profile which is formed of both organic matter and organisms. The upper part of the L-horizon is included although usually traces of the activity of organisms are not visible. He used the horizons L, F, H of Hesselman (1926) and the Ah-horizon is subdivided into: Ln (n: novus), Lv (v: verändert (German) = altered), Fr (r: plant residues), Fm (m: medium plant residue: fine substance ratio), Hr (r: plant residues), Hf (f: fine substance), Ahh (double h for high humus content), Ahu (u: the part of the Ah under the Ahh). These subhorizons are defined by purely morphological features.

Bal (1973: 1982) introduced the term humon to describe the collection of macroscopically and/or microscopically observable organic bodies in soil which are characterised by a specific morphology and spatial arrangement; it is a "natural three-dimensional genetic organic individual" existing in soil.

The differentiation of organic materials in *Soil Taxonomy* and in the *FAO-Unesco Soil Map of the World* legend is achieved by ascertaining the amount of fibrous material present. This is organic debris, the botanical origin of which can be determined, and which is not destroyed by rubbing between the fingers. Fibric material (Oi, Hi) consists largely of material so defined: sapric material (Oa Ha) is most highly decomposed, containing less that 1/6 of its volume of fibrous material, and hemic material (Oe, He) is intermediate in fibre content and state of decomposition.

This terminology was introduced for the organic layers by the authors of *Soil Taxonomy* and the most recent summary appeared in the *Keys to Soil Taxonomy* (Soil Survey Staff, 1987). Three types of organic soil materials were defined: fibric, hemic and sapric according to the degree of decomposition of the original plant materials. The definitions are as follows:

Fibric soil materials Fibric soil materials have the following characteristics:
1. The fibre content after rubbing is three-fourths or more of the soil volume, excluding coarse fragments and mineral layers; or
2. The fibre content after rubbing is two-fifths or more of the soil volume, excluding coarse fragments and mineral layers, and the material yields a sodium pyrophosphate extract colour on white chromatographic paper that has a value and chroma of 7/1, 7/2, 8/1, 8/2, or 8/3.

Hemic soil materials Hemic soil materials are intermediate in degree of decomposition between the less decomposed fibric and more decomposed sapric materials. They have morphological features that give intermediate values for fibre content, bulk density,and water content. They are partly altered both physically and biochemically.

Sapric soil materials These are the most highly decomposed of the organic materials. They normally have the smallest amount of plant fibre, the highest bulk density, and the lowest water content on a dry-weight basis at saturation. They are commonly very dark grey to black. They are relatively stable, ie., they change very little physically and chemically with time in comparison to the others.

In addition to these three basic kinds of organic materials, humilluvic, limnic, coprogenous earth and diatomaceous earth are distinguished.

Those organic materials which are only saturated for a few days during the year are normally thin and lie upon the surface of the mineral soil, especially in undisturbed sites. Except for Canada, UK and New Zealand horizons consisting of these materials are designated O. They include material known as litter, fermentation and humus layers. The Soil Survey of England and Wales appears to be the origin of the recent definitions for these horizons which were used in Canada and New Zealand. The definitions of Avery (1980) are given:

- L Fresh litter deposited during the previous annual cycle. It is normally loose and the original plant structures are little altered.
- F,H Organic horizons originating as litter deposited or accumulated at the surface, and seldom saturated with water for more than a month at a time.
- F Partly decomposed or comminuted litter, remaining from earlier years, in which some of the original plant structures are visible to the naked eye.
- H Well-decomposed litter, often mixed with mineral matter, in which the original plant structures cannot be seen.

Colour

One of the most obvious characters of soil horizons is colour. Soil colour is often indicative of specific soil conditions and of related physical, chemical and biological properties. Thus dark colours are normally indicative of organic matter incorporation in surface horizons or manganiferous concretions in subsoil horizons. Red colours normally suggest freely drained oxidising conditions in iron-rich soil materials, and grey colours saturated or reducing conditions. The presence of carbonates or other more soluble salts may introduce whitish or even pinkish colours into the soil.

Soil horizon descriptions should always include a record of the dominant background colour of a soil horizon in a moist condition (or both dry and moist colours in an arid environment) using the Munsell Soil Colour Charts. In these charts, the range of colours usually encountered in soils is arranged in terms of hue, value and chroma. Where a soil horizon has several colours, the relationship of these colours to structure faces, roots, pores and other features is often of critical importance in assessing the genesis of the horizon being described. This is especially important when describing the mottled effects of gleying.

Although used in a qualitative manner, colour is a specified criterion for several of the diagnostic epipedons of *Soil Taxonomy* . The mollic epipedon is expected to have a dark colour and low chroma; except where there is more than 40 per cent finely divided lime in which case the colour criteria are waived, "both broken and crushed samples must have Munsell colour value darker than 3.5 when moist and 5.5 when dry, and chroma less than 3.5 when moist". Colour requirements for the umbric and anthropic epipedons are similar, but where the colour of an epipedon does not meet these requirements, it falls into the category of an ochric epipedon. As it includes the effects of gleying, colour is also one of the criteria for identification of the cambic horizon: "a. if there is mottling, the chroma is 2 or less, b. if there is no mottling and the value is less than 4, the chroma less than 1; if the value is 4 or more, the chroma is 1 or less; c. The hue is no bluer than 10Y if the hue changes on exposure to air (a hue bluer than 10Y that does not change on exposure is not diagnostic)". Similar criteria are used in the revised FAO-Unesco (1988) Legend for the *Soil Map of the World*, and additionally specifications are given that the soil horizon should be darker than the C horizon, which should be at least one Munsell unit darker in both moist and dry conditions. The Melanic A horizon of South Africa must have dark colours such that "both value and chroma are 3 or less in the dry state but with the exclusion of 10YR 3/3; a value of 4 and a chroma of 1 or less in the dry state is permitted if the horizon is more than 300 mm thick; dusky red colours and hues of 5YR and redder are not permitted". Avery (1980) for the Soil Survey of England and Wales stipulates a moist rubbed colour with a value and chroma of 3 or less for a humose topsoil.

Bleached subsurface horizons, albic horizons, have colour as a definitive criterion. The colour of these horizons is determined mainly by the colour of the minerals rather than any thin or discontinuous coatings on their surfaces. In *Soil Taxonomy* it is stated that: "The colour value, moist, of an albic horizon is 4 or more, or the value, dry, is 5 or more, or both. If the value, dry, is 7 or more, or the value, moist, is 6 or more, the chroma is 3 or less, dry or moist. If the value, dry, is 5 or 6, or the value, moist, is 4 or 5, the chroma is closer to 2 than 3, either dry or moist. A moist chroma of 3 is permitted if the parent materials have a hue of 5YR or redder". The same criteria are applied in the FAO-Unesco (1974) *Soil Map of the World*. Similar criteria have been adopted in England and Wales and in New Zealand where in addition a gleyed eluvial horizon is distinguished by "a dominant moist chroma of less than 3 or a chroma of 3 or 4 and a distinctly higher value (eg. 5/3, 6/4) and yellower hue than the main colour of the underlying horizon". The Eag horizon has "a dominant chroma of 2 or less and few or no ferruginous mottles, attributable to reduction and removal of iron". The South African Soil Survey (MacVicar *et al.*, 1977) gives colour criteria for most hues of an E horizon; "if the hue is 2.5Y, then values of 5 or more and chromas of 2 or less; or values of 6 or more and chromas of 4 or less; if hue is 10YR, then values of 4 and chromas of 2 or less; or values of 5 or more and chromas of 3 or less; or values of 6 or more with a chroma of 4; if hue is 7.5YR, then values of 5 or more with a chroma of 2 or less; or values of 6 or more with a chroma of 4 or less; if hue is 5YR then values of 5 or more and chromas of 2 or less; or values of 6 or more with chromas of 3 to 4; if colour is neutral, then values of 5 or more".

The Australian system of Northcote (1979) uses colour as a criterion to subdivide the division of Duplex soils; those with red clay subsoils (Dr) must have a value/chroma rating (Fig. 2) of 5 and a hue as red or redder than 5YR; those with brown clay subsoils (Db) must have a value/chroma rating of 5 and a hue yellower than 5YR; those with yellow-grey clay B horizons (Dy) must have a value/chroma rating of 2 or 4 apart from those colours of the Munsell gley chart; those clayey B horizons (Dd) with a value/chroma rating of 1; and those clayey B horizons (Dg) the upper segment of which has a value/chroma rating of 3, or any colour on the Munsell gley chart. Subdivisions of other Principal Profile Forms at the next lower level of classification also are based on colour.

In England and Wales (Avery, 1980) and New Zealand (Clayden and Hewitt, 1980), a Bg horizon must meet one of the following colour requirements: "1) moist chroma 1 or less dominant on ped faces, or in the matrix if peds are absent, with or without mottles; 2) moist chroma 2 or less dominant on ped faces, or in the matrix if peds are absent, accompanied by distinct or prominent mottles of higher chroma and/or redder hue. (If ped faces have organic coats with values of 4 or less there must be greyish mottles or matrix colours within peds.); 3) moist value 5 and chroma 3, or moist value 6 or more and chroma 4 or less, dominant on ped faces or in the matrix as above, if either: a) there are common or many prominent mottles, or b) the horizon has a dominant hue of 5YR or redder inherited from reddish (haematitic) parent material and there are common or many, distinct or prominent greyish or brownish mottles".

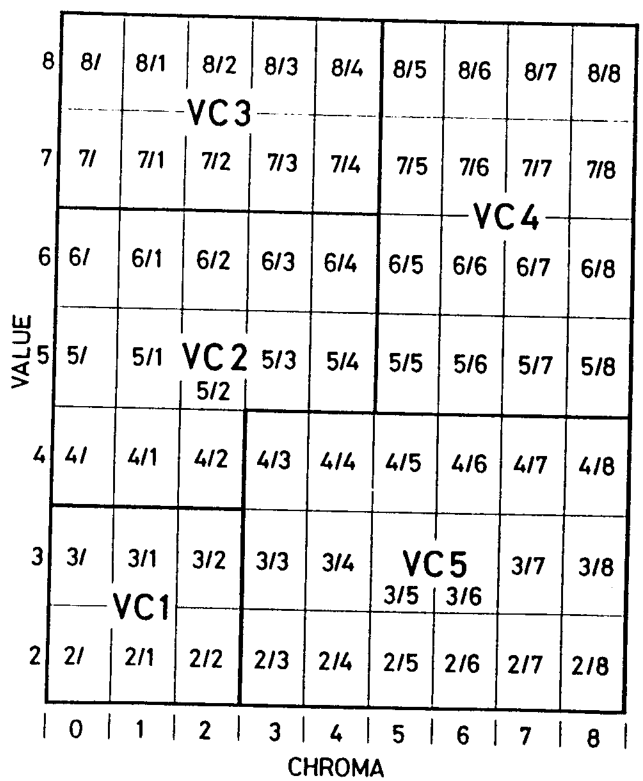

Fig. 2 Value/chroma rating groups for use with colour charts (based on Northcote, 1979).

A Cg horizon is present if the soil material has "a dominant chroma of 2 or less or a colour due to uncoated sand grains. Intensely gleyed Cg horizons in the system of the Soil Survey of England and Wales should have a chroma of 1 or less in yellowish, greenish or bluish hues that change on exposure to air indicating the presence of readily oxidizable ferrous compounds, usually pyrite or vivianite".

Other horizons where colour is a criterion for a named horizon is with podzolic B horizons and prominent Bh horizons with coated grains. In the former the moist chroma should be greater than 3, or the value 3 or less, and in the latter, moist colour and chroma should be 3 or less. The Soil Survey of England and Wales has also utilised colour as a differentiating feature for palaeoargillic horizons which usually underlie (some) present-day soils, but which may also occur directly beneath an A horizon on eroded sites. Palaeo-argillic B horizons must meet the following colour requirements:

1. Dominant matrix colour with hue of 7.5YR or redder, value 4 or more that does not increase by more than one unit on drying, and chroma more than 4 (moist or dry). If the particle-size class is sandy silt loam or coarser, the hue should be 5YR or redder. Hues of 5YR or redder and chroma of 4 are also permitted if the horizon is clayey and the colour is not directly inherited from a reddish pre-Quaternary rock.
2. Many coarse mottles with hues of 5YR or redder and chroma more than 5, or common or many mottles with hues redder than 5YR, not directly inherited from a red or red-mottled pre-Quaternary rock.

The West German Working Group on Soil Systematics (1985) introduces colour into the definition of Bv (cambic) horizons which should have, amongst other features, a more reddish hue than a red coloured bedrock material, a more yellowish hue or higher chroma and/or a higher clay content. Transitional horizons (to sesquioxidic enriched B horizons) should also have redder hues by 0.5 Munsell unit, Bsv, or by one Munsell unit, Bs and Bvs. T horizons (derived from solution residue of carbonate rock) must meet certain particle-size criteria and have "bright brownish yellow to brownish red colour (chroma 5)" and a distinct polyhedral structure. S horizons are those affected by a perched water table. Such soils have pale-coloured spots and ferruginous mottles; Sew horizons (depleted of iron by perched water table) are characterised by a Munsell colour value of mostly 4 and above, 5 when dry, and a value-chroma ratio of 2.5 and above. G horizons resulting from the influence of ground water must have more than 10 per cent rust-coloured mottles, but Gr horizons which are mostly wet for more than 300 days per year must also have "a Munsell colour hue of N1 (black) to N8 (white) or 5Y (grey), 5G (greyish green), or 5B (bluish grey) with a chroma less than 1.5 (if 5G less than 2.5) and 5 per cent of the profile surface covered in rust-coloured mottles".

Structure

Soil structure may be studied at two levels: macroscopically in the field and by the techniques of microscopy in the laboratory. In these ways the pedologist may appreciate those soil aggregates (peds) which are observable with the naked eye as well as the internal organisation of the peds visible only with the aid of optical instruments. Brewer (1964) has described soil structure as "the physical constitution of a soil material as expressed by the size, shape and arrangement of the solid particles and voids, including both the primary particles to form compound particles and the compound particles themselves".

Peds, the natural aggregates in soils are formed as the result of a number of processes. The physical actions of wetting and drying, freezing and thawing are probably responsible for the initial aggregation of the mineral particles. Although soils predominantly formed of sand may be without aggregates, those formed in loamy or clayey materials are aggregated into peds with distinctive shapes. However, clays tend to be massive with fewer and larger structures, especially in the lower horizons. Once initiated by physical processes, the soil structures persist as shrinkage cracks tend to repeatedly re-open along the same planes of weakness. They become lined with clay and organic matter derivatives which help to stabilise the ped faces. Plant roots and micro-organisms also exploit the voids within the soil, the latter are claimed to produce mucilagenous substances which help to bind together aggregates of soil material. Faecal material from soil-living fauna, particularly earthworms, may comprise a large proportion of a soil horizon in some circumstances.

Accounts of the description and recognition of peds are given in the field handbooks of soil survey organisations, most of which have a system derived from the 1951 *Soil Survey Manual* (Fig. 3). This in turn was developed from earlier Russian schemes (Hodgson, 1978). Recent revisions of soil survey handbooks attempt to distinguish between natural structures and aggregates produced by cultivation (clods and fragments), and in recent years increasing attention is being paid to the character of pores, as these are exploited by roots and soil fauna, as well as containing reservoirs of water and atmospheric gases.

In the field, ped shape and arrangement (pedality), or the absence of peds (apedal soils) are obvious, major features which are taken into consideration for horizon recognition. There is a tendency for peds in the horizons near the surface to be *blocky* , and under natural vegetation or high levels of management to be *granular* or *crumb* . Breakdown of structure under poor management can result in *platy* structure. In the middle and lower levels of profiles in temperate regions, there is a tendency for blocky structures to aggregate into *prismatic* peds, but this is rarely seen in soils of tropical regions. A special case occurs with the *columnar* peds with domed tops characteristic of solonetz soils. Persistence or durability of these structures is normally assessed on a scale of structureless, weak, moderate and strong.

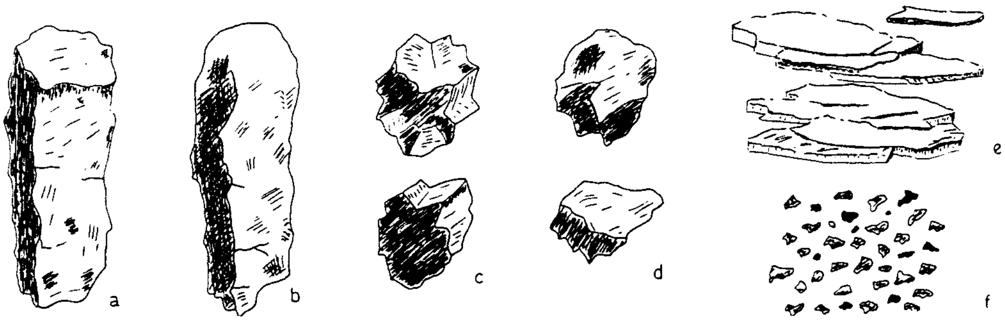

Fig. 3 Soil structure formed by the aggregation of the sand, silt and clay particles: (a) prismatic; (b) columnar; (c) angular blocky; (e) platy; (f) crumb or granular (Soil Survey Staff, 1951).

In Australia, structure of soil horizons is assessed in terms of pedality; the grade of pedality is the "degree, development and distinctness of peds" (McDonald *et al.*, 1984). *Pedal* soils have observable peds which are assessed as weak, moderate or strong. *Apedal* soils are single grain or massive. Pedality expresses the relative "strength or cohesion within peds and the strength of adhesion between adjacent peds". The grade of pedality varies with the soil-water status, but it is described at the moisture content considered normal for a soil. Primary peds, the simplest structures, may be aggregated to form compound peds. Similar concepts of pedality are employed in the definition of horizons in South Africa (MacVicar *et al.*, 1977).

The *Guidelines for Soil Profile Description* (FAO, 1977) treats the air spaces in soils under the heading of pores. As explained previously, spaces are an integral part of the soil, and in some ways are as important as the solid materials which surround them. Measurement of pore space within a soil horizon has yet to be perfected, but Hodgson (1978) following accounts by Benecke (1966) and Renger (1970), suggests the use of packing density to estimate the percentage volume of pores greater than 0.006 mm or greater than 0.002 mm to give some indication of air capacity (at 0.05 bar suction) and storage pore space (air-filled pore space at approximately 15 bar suction). As Tables 1-4 show, these parameters are closely related to particle-size class. In the field, pore spaces may be classed as fissures or pores; fissures are essentially intra-ped pores, and pores occur within the structures. The percentage pore space within horizons is determined by experience, or by comparison with diagrams. The direction and mode of origin should be described when possible.

Table 1 Packing Density

Packing density	g cm^{-3}	Field properties (modified after Benecke; 1966)
Low	<1.40	Loose when moist if single grain; peds if present are fine or medium and easily displaced; weak ped and/or soil strength when moist. (Rarely encountered in clay or sandy clay mineral soils.)
Medium	1.40-1.75	Neither strong nor loose consistence; peds not easily displaced, but may be well formed; weakly developed fine or medium peds, or strongly developed coarse peds with many macropores and moderately firm ped strength.
High	>1.75	Compact if single grain; peds are coarse (angular or prismatic) and structure is normally weakly developed; soils with strongly developed structure have very firm or strong ped strength and few macropores. (Rarely encountered in A horizons unless clay or clay loam.)

Table 2 Porosity Class in relation to Particle-size Class and Packing Density (Pores >60 μm diameter)

Particle-size class		Packing density Low	Medium	High
Sand	All horizons	(EP)	EP	(EP)
Loamy sand	All horizons	EP	EP	(MP)
Sandy loam	A horizons	EP	VP	(MP)
	Other horizons	EP	VP	SP
Sandy silt loam	A horizons	MP	(SP)	*
	Other horizons	EP	MP	(VSP)
Sandy clay loam	A horizons	(SP)	(SP)	*
	Other horizons	*	*	(MP)
Silty clay loam	A horizons	MP	SP	(VSP)
	Other horizons	VP	MP	SP
Silty clay	A horizons	VP	(MP)	*
	Other horizons	*	MP	VSP
Silt loam	All horizons	(MP)	MP	*
Clay loam	A horizons	VP	SP	(SP)
	Other horizons	(EP)	MP	VSP
Clay	A horizons	(MP)	MP	(VSP)
	Other horizons	*	SP	VSP
Sandy clay	All horizons	*	*	*

For definitions of porosity classes see Table 3.

( ) Limited data

* Insufficient information available

Examination of the soil with the aid of an optical microscope enables the nature and "pattern of constituents" to be seen. This pattern is the physical constitution of the soil material as expressed by the spatial arrangement of the solid particles and pore spaces. The features which are included are the skeleton grains, minerals of silt and sand size, and plasma, the material finer than 2 mm which includes the clay minerals. The skeleton grains and plasma together constitute the groundmass, the background material against which additional pedofeatures may be recognised (Bullock *et al.*, 1985). Evidence from soil micromorphology is particularly relevant when considering the presence of an argillic horizon:

> Concentrations of strongly oriented clay covering at least 2 per cent of a representative thin section (Avery, 1980).
>
> Have clay skins on some of both the vertical and horizontal ped surface and in the fine pores or have oriented clay in 1 per cent or more of the cross-section (Soil Survey Staff, 1975; FAO, 1977).

Table 3 Porosity Class

	Porosity class		Pores >60 μm % of soil volume
VSP	Very slightly porous	1	<5.0
SP	Slightly porous	2	5.0-9.9
MP	Moderately porous	3	10.0-14.9
VP	Very porous	4	15.0-20.0
EP	Extremely porous	5	<20.0

Table 4 Storage Pore Space and Packing Density (Pores > 0.2 μm diameter)

Pores >0.2 μm diameter % of total soil volume	Packing density	g cm^{-3}
>36	Low	<1.40
23-36*	Medium	1.40-1.75
<23	High	>1.75

* Sands and loamy sands at medium packing density usually have >36%. Pores >0.2 μm diameter.

Similarly, the evidence of micromorphology is taken into account for the confirmation of the microstructure of the podzolic B horizon and spodic horizon (although the cracked coatings referred to are almost certainly an artifact of thin section preparation):

> Most sand grains or stones coated, or coated and bridged (causing brittleness or cementation), by dark metal-organic complexes which appear isotropic in thin section (Avery, 1980).

> The presence of isotropic cracked coatings ... and pellets ... may have to be confirmed by study of thin sections (Soil Survey Staff, 1975).

The presence of critical amounts of weatherable minerals is significant for the evidence of an oxic horizon:

> Weatherable minerals ... should constitute less than 3 per cent of the fraction between 20 and 200 mm, but mica (muscovite) may constitute as much as 6 per cent of this fraction (Soil Survey Staff, 1975).

Texture

Particle-size distribution is a significant criterion for recognition of soil horizons. As Hodgson (1978) observes, there is a plethora of schemes to measure and name particle-size classes and organisations have evolved standards which are suited to their own local conditions. Although there is an International Scale for the size of soil particles, agreed by the International Society of Soil Science at its first Congress, this scale has been modified in most countries to accommodate the particle range of soils on loessial materials. The limits of particle-size classes adopted in the 1951 *Soil Survey Manual* are shown in Table 5 where they are compared with the International limits.

The particle-size class of the fine earth (material which passes a 2 mm round-hole sieve) in a soil horizon may be assessed by moistening a sample and working it between the fingers and thumb to its maximum plasticity and then estimating the relative proportions of sand, silt and clay present. After comparison with appropriate standards the soil sample may then be allocated to a particle-size class. All pedologists are familiar with the textural triangle upon which the classes may be plotted. However, if slightly different criteria are used then the distribution of classes on the diagram is changed as can be seen by comparison of the systems used in the USDA and the Soil Survey of England and Wales (Fig. 4, a and b), (Vogel, 1986).

Soils vary greatly in the distribution of their particle-size classes. Some profiles are uniform with no change from the surface to the parent material. A common situation is where soils have an increased clay content with depth, but although less common, the reverse also occurs with a finer texture at the surface. Some soils have a gradual change in texture from the surface downwards. In the Australian system of Northcote (1979) these patterns of particle-size distribution have been used as a basis for soil classification. In terms of horizon characteristics, the particle-size is an important criterion and particularly in the argillic horizon.

Table 5 Size limits of soil separates from two schemes of analysis (Soil Survey Staff, 1951)

Name of separate	US Department of Agriculture scheme Diameter (range) Millimetre	International scheme Fraction	Diameter (range) Millimetre
Very coarse sand*	2.0 -1.0		
Coarse sand	1.0 -0.5	I	2.0-0.2
Medium sand	0.5 -0.25		
Fine sand	0.25-0.10	II	0.20-0.02
Very fine sand	0.10-0.05		
Silt	0.05-0.002	III	0.02-0.002
Clay	<0.002	IV	<0.002

* Prior to 1947 this separate was called fine gravel. Now fine gravel is used for coarse fragments from 2 mm to ½ inch in diameter.

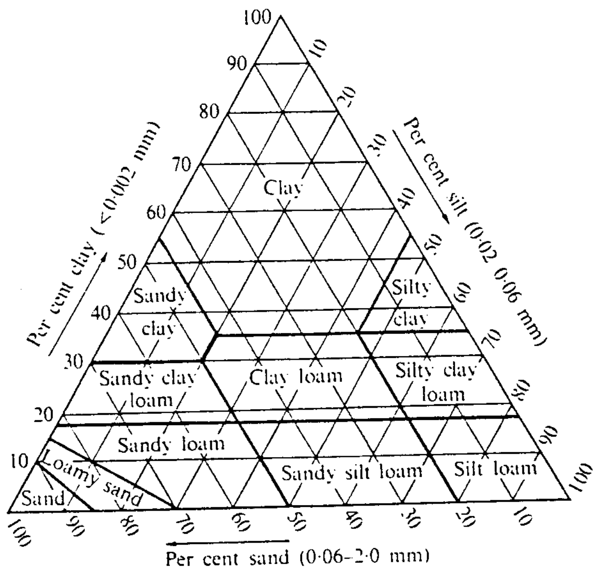

Fig. 4a Particle-size classes, Soil Survey Manual, USDA

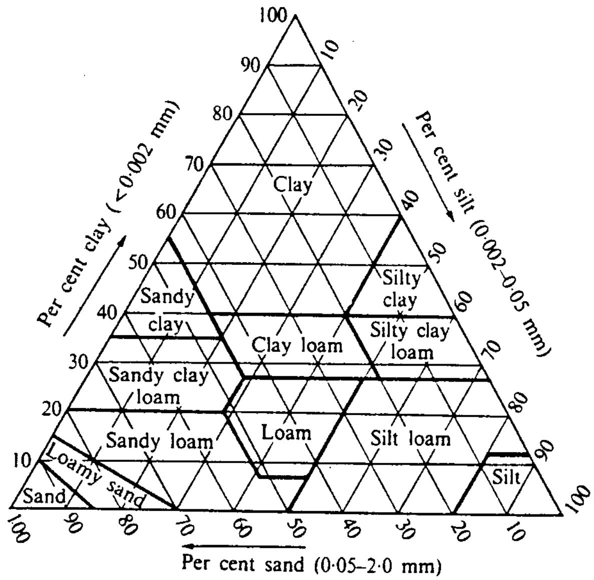

Fig. 4b Particle-size classes, Soil Survey of England and Wales

Consistence

The FAO *Guidelines for Soil Profile Description* indicate that consistence is widely used (and mis-used) as a criterion for identification of soil horizons. The system of assessment adopted by the Guidelines is that of the 1951 *Soil Survey Manual* which describes consistence in wet, moist or dry soil conditions. When wet soil material may be described according to its stickiness and its plasticity on a numerical scale of 0 to 3. In the moist condition assessment is made on a scale of loose, friable, firm, very firm, extremely firm and when dry a scale of loose, soft, slightly hard, hard, very hard and extremely hard. In the system of the Soil Survey of England and Wales, the soil is assessed for its strength, ped strength, its failure characteristics, its degree of cementation as well as its stickiness and plasticity. In *Pochvennia Syemka* (Tiurin *et al.*, 1959) a scale of soft to very firm is employed to describe soil consistence. The Australian *Soil and Land Survey Field Handbook* (McDonald *et al.*, 1984) describes soil consistence in terms of the strength of cohesion and adhesion in the soil. The strength or resistance to breaking or deformation is assessed on a scale from loose through very weak, weak moderately firm, very firm, moderately strong, very strong to rigid. Adherence of the soil material is described on a scale of non-sticky, slightly, moderately and very sticky; a similar scale is used in the description of plasticity and its type by comparison of field texture after an initial 1 to 2 minute working of the sample and after 10 minutes.

An alternative scheme adopted in an earlier version of the Soil Survey of England and Wales handbook was derived from a scheme proposed by Butler (1955). This involved assessment of the cohesion by the amount of force required to disrupt a standard fragment of soil when pressed between the finger and thumb. Similar scales of pulverescence, coalescence and consistence based on these values give plastic, labile, crumbly and brittle soils respectively.

In all determinations of consistence, the soil-water state is of utmost significance as the strength and characteristics of failure are closely linked to the moisture content of the sample. Hence the necessity to assess the consistence at different moisture contents where possible.

Other features

Although the preceding features are important and describe the major characteristics of soil horizons, other features may be significant in particular cases and so deserve brief mention. In common with many other systems of soil profile description, the FAO guidelines include:

Cutans The surface of the peds described under the heading of structure have coatings, pressure faces and slickensides which may be recognised with the naked eye or with a hand lens. In most cases the nature of these cutans requires micromorphological confirmation from a range of constituents which includes clay skins or argillans, ferrans, organans, mangans, soluans, silans and mixture of these, eg. ferri-argillans. The situation, quantity and thickness can be described and used in the deductions made about the genesis of the profile. The absence of such features should also be mentioned in any descriptive account.

Cementation The soil material comprising some horizons may be cemented, limiting water movement and rooting depth. The term cementation refers to material which is irreversibly cemented and so does not break apart when wetted. Sometimes referred to as pans, cemented horizons or layers may be held together by deposits of iron, silica, calcium carbonate, calcium sulphate or organic matter. (Uncemented pans may also arise by the compaction of soil particles by ploughing or by freeze-thaw processes. When taken from the profile fragments of these pans usually become disrupted by immersion in water.) The degree, continuity and structure of cemented horizons and layers may be described with reference to the scales provided in soil survey handbooks.

Porosity Porosity is a term which describes the spaces between peds, sometimes referred to as fissures, and the pores which occur within soil structures. These features are important for the movement of moisture and gases into and out of the soil and provide the soil fauna and roots with easy paths for movement through the mineral material. Porosity may be described in terms of the morphology, continuity, orientation, and distribution of the pores.

Mineral nodules The term nodule is used to describe concretionary and accretionary segregations as well as small patches and residual materials present in a soil horizon. Often referred to as 'neoformations' these features vary in abundance, size and shape as well as colour and constituents. Soil survey guides for profile description provide scales for assessing and describing these features which are often significant in identifying the nature of processes operating within the soil.

Carbonates and soluble salts The presence of carbonates or more soluble salts in a soil profile is strongly related to the moisture regime experienced by a particular soil and by its relationship to the ground-water table. A scale of reaction to 10 per cent hydrochloric acid is used for the presence and abundance of carbonates; other salts may be estimated by taste or by measurement of the electrical conductivity of a saturated paste and individually by chemical analysis.

Biological features Evidence of animal activity in the soil includes features such as krotovinas, earthworm burrows and casts, termite burrows, insect nests, birds nests and droppings. The extreme acidity of podzols limits the range of soil fauna present, so horizonation in these soils is remarkably clear. In other soils, animals are responsible for mixing soil materials and homogenising them, but normally not to the extent that horizons disappear. Ants and termites may be responsible for assembling certain mineral and chemical constituents of soils in their nests, and over longer periods of time they produce the stone lines present in many soils of tropical regions. Roots penetrate the soil mass as far as they are able, reacting to the physical and chemical environment of the soil in which they occur. So, their distribution, size and health are of considerable interest to the pedologist as indicators of soil conditions within the profile and its horizons.

Drainage Soil drainage is normally closely related to the colour of soil materials, but relict features may persist after soils have been drained. The drainage status of a soil is usually measured on a scale of excessive, free, imperfect, poor and very poor based on the visual appearance of individual soil horizons and the whole profile. The drainage state is important because it reflects the extent to which a soil is aerobic or anaerobic; the critical factors being how long a soil remains waterlogged after heavy rain and how long the fine pores remain waterlogged after the large fissures have drained under the influence of gravity. Depending upon the chemical composition, texture, structure and porosity some horizons of soils will develop strong features of gleying, others will not.

pH As it also can be measured in the field, the soil pH value is often considered as a feature of the soil profile which can help to define and describe the character of a soil and its individual horizons. The trend in pH values down a soil profile reflects many of the soil chemical properties as it is related to the degree of base exchange saturation of the cation exchange capacity and to leaching by rainwater percolating through the soil.

Rock fragments The presence of rock fragments in a soil reduces its moisture holding capacity and the amount of soil which plant roots can exploit. Simply defined as that material which exceeds 2 mm in diameter, rock fragments also may be described by size and composition. No special term is used for soil horizons with <15% rock fragments, but class names (pebbles, cobbles, stones and boulders) may be used as modifiers for particle size classes, e.g. stony loam (15-35%), very stony loam (35-60%), extremely stony loam (>60% rock fragments) (Soil Survey Staff, 1981).

The features described in this chapter combine to produce the characteristic morphology of soil horizons within the soil profile. Beginning with the parent material, the result of soil genesis is to increase steadily the degree of anisotropy within the soil material; in other words to cause the gradual development of soil horizons parallel to the soil surface until they are coherent, recognisable parts of the soil profile.

MODIFICATION OF SOIL HORIZONS

The preceding section discussed the morphology of soil horizons; those features which have resulted from the operation of the soil forming processes. Soils are the result of the interaction of a number of factors and so their profile development reflects a balance of these factors. If the factors are changed, then the nature and morphology of the soil horizons may also change. Jenny (1941) proposed an equation for the factors of soil formation and further refined it in subsequent publications (Jenny, 1961, 1980). Simonson (1959) viewed soil formation as the result of additions, substractions, transformations and translocations. These approaches enabled soils to be seen as existing in a state of dynamic equilibrium and therefore the possibility exists of their modification or even destruction as well as their formation. Although explicit in most dynamic concepts of soil genesis, only a few soil scientists have examined this idea, even though many examples exist of relict soils, palaeosols and soils upon which current processes have superimposed a different profile form. The processes which cause change to take place in soil horizons may be summarised under the headings of physical, chemical and biological activity.

Physical processes

The most obvious disruption of soil horizons is by soil erosion. Raindrop impact can destroy the structure of the surface peds by separating the mineral and organic fractions. These may then be removed by overland flow or percolation through the soil to reach the streams. Erosion by wind may occur also, removing the finer material and possibly forming the remaining sand fraction into dunes.

Expansion and contraction with wetting and drying cycles are physical processes which are particularly apparent in fine-textured soils dominated by smectite clays. It is claimed that these processes limit horizonation in vertisols because the material is constantly being churned, but in fact the processes produce a horizon morphology of a special nature. Similarly, the growth of ice and salt crystals is claimed to lead to homogenisation of soil material and limitation of soil horizon development, but such concepts are based of the formation of leached soils which are only one form of soil development. Climatic conditions have changed in many parts of the world and so examples may be found of those processes which are modifying soil horizons, developed under different climatic conditions. Features attributable to soil formation under tundra conditions are widespread throughout northern Europe, North America and Asia lying below and within horizons formed in the present-day climatic conditions.

Chemical processes

Modification of soil horizons by chemical change within the soil can also occur. Several examples of soil sequences where changes in chemical composition are documented occur in the literature. Lowering of the ground water can lead to the oxidation of peat and prolonged cultivation can result in its complete disappearance. The degradation of brown forest soils through desaturation and clay movement has been discussed by Pedro *et al.,* (1978).

Remobilisation of aluminium, iron or humus may occur in podzol profiles leading to the gradual migration downwards of the B horizon or even of its destruction. Similarly, it is possible for the mobilisation of soil materials to occur in the upper part of a profile beneath a peaty mat resulting in a strongly gleyed horizon in upland soils in a maritime environment (Bridges, 1974).

The accumulation of calcium carbonate, derived from wind-blown dusts in the soils of semi-arid regions can completely change the soil horizon in which it is accumulating (Fig. 5) as has been documented by Gile *et al.* (1965; 1966; 1981; Gile and Grossman, 1979). In areas where a wetter climate has followed a dry period suitable for calcium carbonate accumulation, the complete or partial removal of carbonates from the profile by leaching can also result in morphological change.

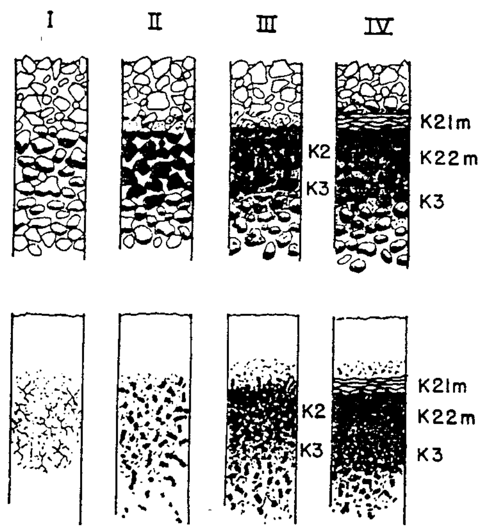

Fig. 5 Schematic diagram of the diagnostic morphology of the stages in the morphogenetic sequences of carbonate horizon formation in gravelly and nongravelly materials. Carbonate accumulations are indicated by black forms and shadings for clarity (Gile *et al.*, 1966).

Biological Processes

Biological disturbance of soil material is claimed to be the most significant of the processes which inhibit the development of soil horizons, and the example of the podzol profile is used to demonstrate horizon formation where there is restricted biological activity. However, well-developed horizonation is present also in many soils with a high level of biological activity. Examples of tree-tip mounds are present in woodlands and the activities of the larger soil-living animals and birds are well known. These are responsible for mixing the soil and homogenising its constituents within the solum depth. A comparison of strongly acid soils, such as a podzol, with eutrophic brown earths demonstrates the efficacy of earthworms in mixing soil materials. The absence of earthworms in the podzol is one of the reasons for its strongly developed horizons.

The activities of man in liming, fertilising and cultivating soil also is reflected in the destruction of some features and the development of new ones. The Belgian soil which figures as Plate 1B in *Soil Taxonomy* demonstrates that land management can influence the development or destruction of soil horizons. This soil, originally a brown earth under forest, developed a strong illuvial B under *Calluna* , which was then partly broken down by the application of lime and nitrogen from manure.

Age of soil and horizon development

The soil profile gradually evolves by the development of horizons with different characteristics from the parent material which does not have a pedological organisation. Young soils retain many of the features of the parent material, but as soil formation proceeds, the definition of the horizons within the soil profile becomes increasingly clear at both macro- and micromorphological levels of organisation. By careful selection of site and soil it is possible to demonstrate for many parent materials a sequence from very young soils with weakly developed profiles to mature soils with strongly developed horizons in their profiles. However, in certain circumstances the processes operating limit the amount of horizon development (negative feedback).

Soil development normally takes place along an asymptotic curve, the shape of which depends on the nature of the soil and the character being studied. Organic matter may build-up rapidly to reach a steady state but the accumulation of clay to form an argillic horizon requires a much greater length of time to achieve a recognisable level of development. The features of an Acrisol (Ultisol) take a much longer period of time to develop than those of an Cambisol (Inceptisol).

In the recognition of horizons, and also in their use in classification, it is necessary to make arbitrary divisions along these curves of development. In Figure 6 organic matter may be visually obvious at 1, where clay accumulation may become apparent only at position 2, much later in the time-scale of development. The degree of development of the argillic horizon may not become significant for classification purposes until position 3 on the development curve. However, the field pedologist cannot ignore the development which has taken place between positions 2 and 3 as it is part of the visual and quantifiable morphology of the horizon.

Bilzi and Ciolkosz (1977) and Harden (1982) show how horizon characteristics may be quantified and combined in a soil development index. It has been suggested that an indication of the degree of development of features, or of horizons themselves, would be a useful concept to be incorporated into the horizon designation. Comparative terms are already used in the description of structure or degree of cementation etc, but the degree of development in other types of horizon is a complex subject and one which departs increasingly from objective assessment, and it needs more consideration than is presently possible.

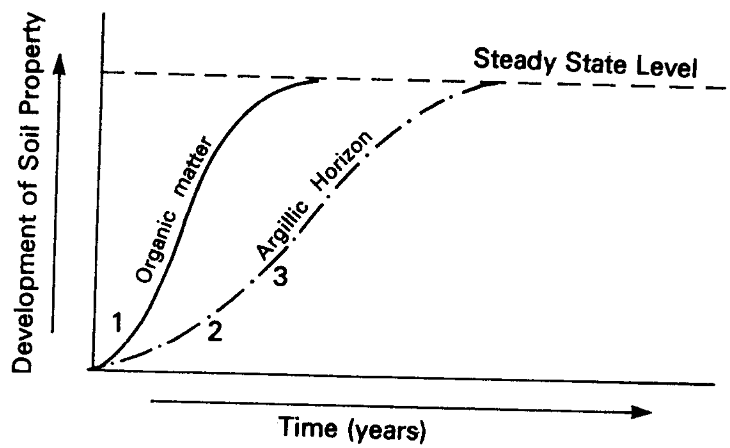

Fig. 6 The asymptotic nature of soil development

GENETIC SOIL HORIZON DESIGNATIONS

Designation of soil horizons by letters of the alphabet may be traced back to studies carried out by Dokuchaev and Sibirtzev on chernozem soils towards the end of the nineteenth century. The origins of soil horizon designations may never be known for certain, but what appeared to begin as a simple, ordered labelling of the horizons present in a soil profile, had by the turn of the century, grown and had acquired a strong genetic connotation.

Reference to Dokuchaev's writings shows that he was a very systematic worker, carefully listing sections of both geology and soils in his writings. Reading these foundation contributions to soil science of the last century, it is possible to see how Dokuchaev's systematic labelling of geological sections with A, B, C, or with 1, 2, 3, was carried over to his soil profile descriptions. In the collection of Dokuchaev's works entitled Russian Chernozem (translated N. Kramer, 1967) the use of ABC occurs in descriptions of soils in the Chern and Novosil districts: at the village of Kazarino he describes

A homogeneous chernozem
B transitional horizon
C subsoil yellowish-brown loess

However, in the same part of the account he uses the letters A, B and C to label alluvial accumulations in the banks of the Kachnya river near the village of Milyukovo, but on the following page he uses the ABC nomenclature for the soil horizons again. An early example of the use of the ABC designations is given by Kasatkin and Krasyuk, 1917 (quoted by Hodgson, 1978).

Other people followed Dokuchaev's lead, but problems arose when the ABC labels were applied to soil types other than chernozems. The general principle of illuviation in podzols was put forward by Vysotsky but several years were to pass before a clear picture of eluvial and illuvial horizons was established (Muir, 1961). Zakharov (1932) proposed that the following letters should be used to symbolise soil horizons:

A upper humus horizon
B transitional or podzolic-eluvial horizon
C illuvial (ortstein)
D parent material

This usage of symbols for horizon designation continued among some Russian pedologists until 1930 when the form proposed by Glinka:

A eluvial
B illuvial
C parent material

with the addition of numerical subscripts for horizon subdivisions became the standard procedure (Muir, 1961). In this way the idea of subdivisions of the soil profile into master horizons became established. Although it was to be several years before the Russian ideas were to reach western European countries and the United States, Ramann (1911) was already describing in detail the meaning of the designations ABC:

A horizon (comprising topsoil) with humus mixed throughout, usually dark-coloured soil layer. The upper part contains humus which still retains evidence of plant structure and is equal to moder. The lower parts of this horizon are characterised by dark staining. This is the horizon of eluviation, dominated by leaching.

B horizon (comprising subsoil) the weathering layer of soils. It is possible to distinguish: 1) leaching through the action of humus is strongly expressed; 2) by a process of mechanical addition of material the layer of ortstein is formed.

C horizon The raw soil (substrate) from which the A and B horizons have been formed by weathering. No chemical action of weathering can be distinguished by the naked eye, but physical disruption can be seen.

Ramann (1917; trans Whittles, 1928) remarks that the Russians use the symbols ABC in a different sense from that of toposil, subsoil and parent material. The symbol A was used to denote an eluvial horizon from which substances were removed by leaching and B represented an illuvial horizon which has been enriched by substances from the horizon above. Ramann supports the idea of the designation by the letters ABC but makes the point that the names eluvial and illuvial, developed from the investigation of podzol soils, can only be applied to soil where there is a downwards movement of material; they are inappropriate in arid areas where the B horizon may be enriched from below, or in many other cases where the B horizon does not receive any additions at all.

The use of ABC system of horizon designation during the second decade of the twentieth century is documented in the *Handbuch der Bodenlehre* (Ruger, 1930). The system is demonstrated in several typical profile descriptions, but from the text it is apparent that the A horizon was regarded as topsoil the B horizon as subsoil and the parent material as the C horizon.

Soil profile description using the ABC system of horizon designation had been included in *Die Typen der Bodenbildung* (Glinka, 1914), but it was not until 1927 that an English version, translated by Marbut as *The Great Soil Groups of the World and their Development* , was published in the United States. This paved the way for the eventual adoption of the ABC system designations by the USDA in the *Soil Survey Manual* (Soil Survey Staff, 1951).

Some of the points made in this review were already apparent to the authors of the *Soil Survey Manual*. These include the use of horizon designations as a means of easy communication, the interpretive nature of designations and the problems of application to different soil types around the world. The system of soil horizon designations presented in the *Soil Survey Manual* and shown diagrammatically in Fig. 7, is as follows:

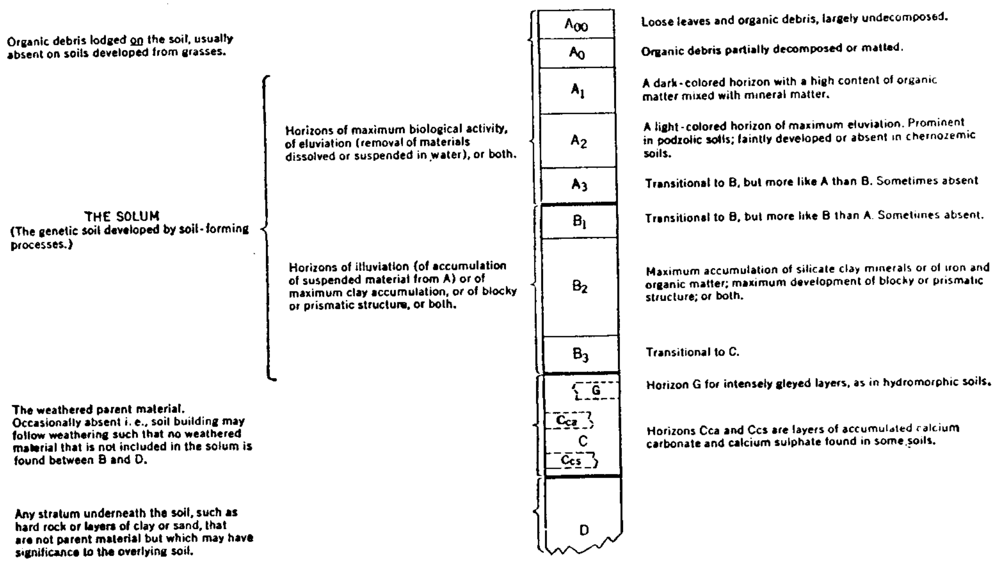

Fig. 7 A hypothetical soil profile having all the principal horizons. It will be noted that horizon B may or may not have an accumulation an have accumulation of clay. Horizons designated as Cca usually appear between B2 and C. The G may appear directly beneath the A (Soil Survey Staff, 1951).

The following section of this report is quoted verbatim from the *Soil Survey Manual* (Soil Survey Staff, 1951).

The A_o and A_{oo} horizons

The A_o and A_{oo} horizons lie above the A_1 horizon of unploughed soils. They are not strictly parts of the A horizon or of the solum as herein defined, although, from some points of view, they might be so regarded[1]. The exclusion of these horizons from the solum in no way suggests that they are unimportant

[1]Some letter other than A would be chosen by the authors for these layers if the use of A_o and A_{oo} were not so well established.

or that careful recognition is not essential to a useful description of many soils. Many important soil forming processes owe their origin in part to materials produced in these layers. Although these horizons have typical thicknesses and characteristics for any one soil type under the normal undisturbed vegetation, their actual thicknesses vary widely because of fire and other common disturbances. These horizons are especially well developed in Podzols and are found on most unburned forested soils, although they are exceedingly thin on some. Thin but important A_0 or A_{00} horizons are occasionally found also on soils developed under grasses and desert shrubs.

A_{00} horizon This is a surface horizon consisting of relatively fresh leaves, twigs, and other plant remains, generally of the past year.

A^0 horizon This is a surface horizon, below the A_{00} if present, and above A1; it consists of partly decomposed or matted plant remains.

The letters L, F, H, or others to indicate the character of the organic material may be used in the description of A_{00}, A_0, and A_1 horizons in addition to the designations suggested, but not in place of them[1]. Subdivisions of A_0 horizons are made as they are for any others.

The A_0 and A_{00} horizons are measured upward from the top of the A_1, if present, otherwise from the upper mineral soil horizon. It is important to observe this convention. The thickness of the A_0 and A_{00} horizons varies so greatly with fire that the surface of the A_1, or upper mineral soil, must be used as a general reference point rather than the upper surface of the A_{00}.

The A horizon

The A horizon is a master horizon consisting of (1) one or more surface mineral horizons of maximum organic accumulation; or (2) surface or subsurface horizons that are lighter in colour than the underlying horizon and which have lost clay minerals, iron, and aluminum with resultant concentration of the more resistant minerals; or (3) horizons belonging to both of these categories.

The A horizon, and especially the A_1, is the horizon of maximum biological activity and is subject to the most direct influences of climate, plants, animals, and other forces in the environment. In a sense, the A protects the rest of the soil; and in it many of the most important soil-building forces have their origin.

When the A horizon is used without subscript numbers, it refers collectively to all the subhorizons in it, excluding A_0 and A_{00}. The sub-horizons are named and described in the following paragraphs.

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[1]Heiberg, S.O. and Chandler, R.F., Jr. A revised nomenclature of forest humus layers for the northern United States. *Soil Science* 52(2):87-99, illus. 1941; and Lunt, H.A. *The Forest Soils of Connecticut.* Conn. Agr. Expt. Sta. Bul. 523, 99 pp, illus. 1948.

A1 horizon This is a surface mineral soil horizon having a relatively high content of organic matter mixed with mineral matter, usually dark in colour. It may or may not be a horizon of eluviation. In nearly all soils it is the horizon of maximum biological activity and is subject to the greatest changes in temperature and moisture content. It is very thick in Chernozems and exceedingly thin in many Podzols. In some Podzols, Ground-Water Podzols, Ground-Water Laterites, and other soils, it is destroyed by repeated fires. Measurements of all horizons are referred to the top of the A_1, if present.

A_2 horizon This surface or subsurface horizon, usually lighter in color than the underlying horizon, has lost clay minerals, iron, or aluminum, or all three, with the resultant concentration of the more resistant minerals. It is an horizon of eluviation - of leaching of materials out in solution and suspension[1]. Much of the dissolved and dispersed material, including clay, moves completely out of the whole soil, not simply into the B horizon. The A_2 is the principal grey or light-coloured leached layer in Podzols (bleicherde), solodized-Solonetz, Planosols, and podzolic soils generally.

A_3 horizon This is a horizon transitional to the B but more like the A than B. (If a transitional horizon between A and B is not clearly divided, and especially where it is thin, it may be designated AB).

A_p horizon This is a ploughed or otherwise mixed surface horizon including more than the original A_1 horizon. The subscript letter p indicates disturbance, usually by cultivation but occasionally by pasturing. Where the plough layer is entirely within the A_1 horizon, it is designated as A_{1p}.

The B horizon

The B horizon is a master horizon of altered material characterised by (1) an accumulation of clay, iron, or aluminium, with accessory organic material[2]; or (2) more or less blocky or prismatic structure together with other characteristics, such as stronger colors, unlike those of the A or the underlying horizons of nearly unchanged material; or (3) characteristics of both these categories. Commonly, the lower limit of the B horizon corresponds with the lower limit of the solum.

Actually the accumulation of clay and the development of blocky or prismatic structure are covariant in many soils, but not in all of them. The relatively small accumulations of total clay in the B horizons of typical Chernozem and Chestnut soils, and in some Podzols, are not primarily responsible for their designation as B horizons.

Commonly the B is called an illuvial horizon, in the sense that colloidal material carried in suspension from overlying horizons has lodged in it. We

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[1]A horizon with B or C resulting, for example, from leaching by water moving laterally through a gleyed layer, may fall within this concept of an A2 horizon.

[2]Organic material is the chief added constituent in the B horizon of some Ground-Water Podzols and in 'humus' Podzols.

must recall, however, that the clay in B horizons may also originate from differences of residual clay formation in place or by recombination of soluble materials brought into it in true solution. Texture differences between A and B horizons may also arise partly from differential destruction of clay, as in Red-Yellow Podzolic soils for example, as well as from illuviation and residual formation in place. When B horizon is used without subscript number or letter, it refers collectively to all the sub-horizons in it. These subhorizons are named and defined as follows:

B_1 horizon This horizon is transitional to the A above, but more like the B than A.

B_2 horizon This is the subhorizon of (1) maximum accumulation of silicate clay minerals or of iron and organic material; or (2) maximum development of blocky or prismatic structure; or may have characteristics of both. In B_2 horizons having both these features but separated, the horizons need to be subdivided into B_{21} and B_{22}, as appropriate.

B_3 horizon The B_3 horizon is transitional to the C horizon, but more like the B than C.

The C horizon

The C horizon[1] is a layer of unconsolidated material, relatively little affected by the influence of organisms and presumed to be similar in chemical, physical, and mineralogical composition to the material from which at least a portion of the overlying solum has developed. Any slight alteration of the upper part of the C, such as reduction of calcium carbonate content in glacial till, unaccompanied by other changes, is designated as C_1.

The D layer

The D layer is any stratum underlying the C, or the B if no C is present, which is unlike C, or unlike the material from which the solum has been formed. The designation D_r is for consolidated parent rock like that from which the C has developed or like that from which the parent material of the solum has developed if no C is present.

Other horizons

[1]Although commonly used and understood, the C is not strictly a soil horizon as herein defined, partly because it is little modified by biological processes in soil formation, and partly because it often has an undetermined lower limit.

Besides the common horizons already defined, there are others that occur importantly but less regularly.

G horizon This is a layer of intense reduction, characterised by the presence of ferrous iron and neutral grey colors[1] that commonly change to brown upon exposure to the air. It is a characteristic horizon in soils developed wholly or partly by gleying. This process involves saturation of the soil with water for long periods in the presence of organic matter. One may speak appropriately of a "gley (glâ) soil" but hardly so of a "gley horizon", since the genesis of the whole profile is involved. Besides the G, other horizons may be somewhat gleyed, indicated by the subscript g. Occasionally it may be necessary to differentiate in the description between fossil gley and active gley. Intergrades between B and G and between C and G may be indicated as BG and CG if more strongly gleyed than indicated by Bg and Cg.

The G horizon is usually included as a part of the solum, along with A and B, but those G horizons occurring within the C or beneath it are not.

C_{ca} horizon This is a layer of accumulated calcium carbonate below the solum and within the C. Such horizons are characteristic of most chernozemic and other soils of subhumid and semi-arid regions. The C_{ca} horizon is not always clearly expressed in Chernozems and sometimes can be detected only by laboratory methods. It is found in some Prairie soils and in some podzolic soils, especially those developed from highly calcareous unconsolidated material. It is often referred to loosely as the "lime horizon" or the "lime zone". This layer may be thin or thick, and soft or very hard. Generally, the thickness and hardness increase from cool to warm climates. In cool and cool-temperate regions the hard layers are found mostly in gravel. In warm semi-arid regions this layer becomes so thick that it can no longer be regarded strictly as a soil horizon. Although the explanation of its genesis is not wholly settled, broad geological processes have undoubtedly contributed, as well as those included under soil formation. The term caliche is applied to C_{ca} horizons, especially to the thick ones in the warm countries of the Western Hemisphere. For the hardened ones, croûte calcaire is an alternative term for hardened caliche.

Formerly Cc was used for what is now designated as C_{ca}. The subscript ca can also be used for accumulations of calcium carbonate in other horizons or layers.

C_{cs} horizons This is a layer of accumulated calcium sulfate within the C. Such horizons commonly occur beneath the C_{ca} horizons of chernozemic soils. The subscript cs may also be used for accumulations of calcium sulphate in other horizons or layers.

(End of quotation from Soil Survey Manual).

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[1]Some G horizons have olive colors - a few too nearly green for the standard color chart.

Not all soil scientists were convinced of the value of the ABC system of horizon nomenclature. The confusion which existed in the USSR before Glinka introduced the present ABC system has already been commented upon.

In 1927, Vilensky attempted to develop an alternative system for soil horizon designations which was based on the first letters of the genetic process responsible for horizon development. These were A accumulative, E eluvial, I illuvial. It is interesting to note that this system was used on some of the collection of soil monoliths sent from Russia to Washington for the First International Congress of Soil Science. These monoliths now form part of the collection at ISRIC - see discussion in Sokolovsky (1932)). Vilensky's scheme, (here quoted verbatim) from Zakharov (1932) is as follows:

Accumulative horizons (A)
  Humous -- Ah
  Boggy -- Ab
  Saline -- As
Eluvial horizons (E)
  From which carbonates are washed out -- Ec
  From which organic substances commence to be washed out -- E
  In case of podzol soils -- Eh
  In case of solonets and solonetsous (alkali and alkaline) soils -- Ea
Illuvial horizons (I)
  Containing carbonates -- Ic
  Containing readily soluble salts -- Is
  Colloidal horizons of podzolised soils -- Ip
  Colloidal in solonetz and solonetsous (alkali and alkaline) soils -- Ia
  Swampy (gley) horizon -- G
  Laterised horizons -- L
  Effervescence line -- s
Parent rock -- P (M)
Underlying rocks -- U.
Intermediate horizons might be denoted by several letters, for instance hcA -- humus horizon containing carbonates, and so on. Horizons may be subdivided into subhorizons.

At the Second International Congress of Soil Science, Sokolovsky (1932) suggested that horizons be designated by the letters H humus, E eluvial, and I illuvial following the earlier ideas of Vilensky. He further suggested that a profile could be designated by letters with the depth of the horizons in figures similar to a chemical formula: he gives the example of a podzol

$$HE_{14}E_{14}EI_{40}IP$$

At the Second International Congress, Sokolovsky was supported by Zakharov (1932) who considered the approach to be a natural development of the genetic concept because it assessed the morphological results of the soil forming processes. Zakharov noted that besides humus, peat and soluble salts, lime, iron oxides may also accumulate in the A (accumulation) horizon. Secondly, he argued that eluvial horizons should be characterised by substances remaining, rather than those which were washed out, and in the same manner illuvial horizons should be characterised by the substances present. (Again the table is quoted verbatim from the original article).

Accumulative horizons (accumulation) A

Humous	Ah -- humi
Humous soddy	Ace -- cespites
Peaty	At -- turbi
Humous saline	Ahs -- Hymuso-satis
Humous carbonatic	Ahc -- humuso-calcaris
Humous ouchre	Aho -- humouso-ochris
Humous lateritic	Ahl -- humuso-lateritis

Eluvial horizons (eluviales) E

Eluvial as to soluble salts but still containing $CaCO_3$ -- EC

Eluvial still containing sesquioxides (R_2O_3) -- E feal

Eluvial still containing a small quantity of R_2O_3 and SiO_2 (in solonetsous alkali soils) -- E sial (a)

Eluvial chiefly containing SiO_2 (in podzols) -- E si (p)

Eluvial containing protoxides of Fe (in bog soils) -- Eg

Illuvial horizons (illuviales) I

Illuvial with soluble salts -- Is

Illuvial with gypsum ($CaSO_4$) -- Igy

Illuvial with lime carbonate -- Ic

Illuvial with sesquioxides (R_2O_3) in colloidal state in podzols -- I feal (p)

Illuvial compact with sesquioxides R_2O_3 and partly SiO_2 in colloidal state (in solonets-alkali soils) -- I sifeal (a)

Illuvial with protoxides and oxides of iron (in bog soils) -- IOG

Illuvial containing sesquioxides and organic compounds (humus) (podzol-bog soils) -- I hfeal

The upper arable horizon may be denoted as buried horizons -- by adding the letter f (funebris) -- Af

Horizons of an intermediate composition may be foreseen, as well as sub-horizons and two-storey illuvial horizons which should be denoted by letters with figures.

The new designations seem to be more complicated, but they will contribute to precise the understanding of separate horizons and of the soil as a whole.

These early morphogenetic proposals for soil horizon designations appear to have been overlooked by successive generations of soil scientists until the great increase in knowledge about soils which occurred following the Second World War. It became increasingly evident that there were difficulties in the application of the genetic ABC system to certain soils in widely differing parts of the world.

Nye (1954) found it preferable to indicate soil horizons in Ghana to two primary horizons: a creep (C_r) horizon and a sedentary (S) horizon. Using a morphogenetic approach he identified horizons formed from worm-cast material (C_{rW}), horizons formed from termite activity (C_{rT}) and horizons of gravel accumulation (C_{rG}). These horizons rested upon the sedentary horizons which were simply allocated to S1 where there was little decomposed rock fragments visible; S_2 where there were many decomposed rock fragments present and S_3 where the altered rock was present, still showing the lithological structures of fresh rock.

Watson (1964) in Zimbabwe encountered similar problems in his study of a soil catena on granite parent materials. He used the symbols:

S for coarse material composed of rock fragments, generally quartz
F for coarse material composed of ironstone gravel
F/S where ferricrete predominates over stone material
M for finer-grained material
W for weathered rock (argillaceous and arenaceous)
G for gley horizons

Both authors indicated that although the 'classical' ABC horizons could be identified in some soils, these divisions of soil morphology were generally more important and cut across the divisions that could be made using conventional horizons.

The need for greater accuracy and pressure for quantification in soil descriptions during the 1950s and subsequent years has led soil survey organisations and individual researchers to propose stricter definitions for soil horizons. As knowledge about soils increased, there was a necessity to redefine concepts to include the results of research as well as to include features not previously known. Thus this period witnessed definitions which had been increasing in detail as specific criteria were introduced to meet particular problems. With hindsight it appears that in the search for better horizon designation soil scientists had already begun to move away from the genetic ABC system.

Master horizons

A master horizon has been described as "a dominant kind of departure from the assumed parent material" (FAO-Unesco, 1974). Normally, a soil profile will have one or more master horizons which reflect the results of the soil forming processes in the organic, upper, middle and lower positions of the profile.

Since the time of Dokuchaev and Sibirtzev the letters A and B have been used to denote the eluvial and illuvial horizons of the soil profile, with the letter C used to designate the parent material and D a deeper rock material (Gerasimov, 1967). Russian pedologists use the nomenclature described in *Pochvennia Syemka* (Tiurin *et al.*, 1959), a translation of which is as follows: "The upper part of the soil profile, where the most intense effect of the soil forming processes occurs, under the influence of living organisms, and where the soil is strongly influenced by accumulation of organic matter, is designated by the letter A." The A horizon is subdivided into subhorizons and the mainly organic surface accumulation is defined as: "A_o - the uppermost part of the soil profile includes an accumulation of the vegetable residues in various stages of decomposition beginning with dead but still preserved material (dead leaves, needles, branches, fruits, frequently associated with mosses) and finishing with completely decomposed material, humus. The A_o horizon is especially characteristic of woodland soils and heath soils; peaty forms are designated by A_T."

Russian definitions of the mineral soil horizons, contained in *Pochvennia Syemka*, may be translated as follows, showing a close agreement with the definition given in the 1951 *Soil Survey Manual*:

> A: Humose, dark-coloured horizon in which the maximum accumulation of organic matter occurs and in which organic matter is closely combined with the mineral matter of the soil. According to the type and amount of humus, this horizon acquires different colours from black to light grey. Depending upon the thickness and morphological appearance it is possible to subdivide into subhorizons designated A_1, A_2, etc.
>
> A_1: The upper, darker-coloured humus-enriched horizon in which there occurs significant breakdown of alumino-silicate clays accompanied by the formation of more mobile forms of organic matter (as in podzols, grey and brown forest soils, solodic soils and solonetz).
>
> A_2: The underlying, light-coloured (light grey or white), more friable, often flaky or without structure, lacking in humus and clay material and relatively enriched with residual silica. This horizon occurs in podzolic soils, podzolized soils and solodic soils.
>
> B: In soils where there is destruction of basic aluminosilicates, the B horizon has an illuvial character. Accumulation of oxidised iron and aluminium occurs by inwashing together with other colloidal material. The horizon possesses greater compactness, increased clay content, brown colours and usually coarser structures, etc. The B horizon can be subdivided into B_1, B_2 and B_3.

In soils where there is no evidence of eluviation of aluminosilicate material (e.g. Chernozems, Chestnut soils, etc.) the B horizon appears as a transition where organic accumulation becomes less and the influence of parent material increases. It can be subdivided into B_1, B_2 and B_3 subhorizons according to the amount of organic matter present. If there is a large amount of calcium carbonate present, then it is possible to designate such horizons by the letter K.

In *Pochvennia Syemka* the C horizon is described as "lacking in humus and evidence for soil formation other than enrichment by carbonates or gypsum". It is further stated that these characteristics can be indicated by the nomenclature: *Ck* - carbonates, *Cc* - gypsum or sulphate. The symbol D is used for a deeper rock stratum which underlies the soil, and the symbol G for a horizon with "constant or prolonged periods of wetness which lead to distinctive features such as greyish, bluish or dirty green colours, rusty markings, black or lilac-tinged patches, bogginess, stickiness, etc".

Reference to the American *Soil Survey Manual* (1951) shows that the horizons of the solum, only the A and B horizons, were defined as master horizons. The overlying organic materials and the parent material beneath being described as layers. In the 1962 *Supplement* to this volume the idea of master horizons was extended by the inclusion of an O horizon of organic materials. The C horizon was referred to as a "mineral horizon or layer excluding bedrock" and the consolidated bedrock beneath was designated R. Both these subdivisions of the soil profile were accorded emboldened typescripts and were ranked as master horizons with the following descriptions, quoted verbatim:

Master horizons and layers

Organic horizons

O Organic horizons of mineral soils. Horizons: (1) formed or forming in the upper part of mineral soils above the mineral part; (2) dominated by fresh or partly decomposed organic material; and (3) containing more than 30 per cent organic matter if the mineral fraction is more than 50 per cent clay, or more than 20 per cent organic matter if the mineral fraction has no clay. Intermediate clay content requires proportional organic-matter content.

O*1* Organic horizons in which essentially the original form of most vegetative matter is visible to the naked eye.

O2 Organic horizons in which the original form of most plant or animal matter cannot be recognised with the naked eye.

Mineral horizons and layers

Mineral horizons contain less than 30 per cent organic matter if the mineral fraction contains more than 50 per cent clay or less than 20 per cent organic matter if the mineral fraction has no clay. Intermediate clay content requires proportional content of organic matter.

A Mineral horizons consisting of: (1) horizons of organic-matter accumulation formed or forming at or adjacent to the surface; (2) horizons that have lost clay, iron, or aluminum with resultant concentration of quartz or other resistant minerals of sand or silt size; or (3) horizons dominated by 1 or 2 above but transitional to an underlying B or C.

A_1 Mineral horizons, formed or forming at or adjacent to the surface, in which the feature emphasised is an accumulation of humified organic matter intimately associated with the mineral fraction.

A_2 Mineral horizons in which the feature emphasized is loss of clay, iron, or aluminum, with resultant concentration of quartz or other resistant minerals in sand and silt sizes.

A_3 A transitional horizon between A and B, and dominated by properties characteristic of an overlying A_1 or A_2 but having some subordinate properties of an underlying B.

AB A horizon transitional between A and B, having an upper part dominated by properties of A and a lower part dominated by properties of B, and the two parts cannot conveniently be separated into A_3 and B_1.

A&B Horizons that would qualify for A_2 except for included parts constituting less than 50 percent of the volume that would qualify as B.

AC A horizon transitional between A and C, having subordinate properties of both A and C, but not dominated by properties characteristic of either A or C.

B Horizons in which the dominant feature or features is one or more of the following: (1) an illuvial concentration of silicate clay, iron, aluminum, or humus, alone or in combination; (2) a residual concentration of sesquioxides or silicate clays, alone or mixed, that has formed by means other than solution and removal of carbonates or more soluble salts; (3) coatings of sesquioxides adequate to give conspicuously darker, stronger, or redder colors than overlying and underlying horizons in the same sequum but without apparent illuviation of iron and not genetically related to B horizons that meet requirements of 1 or 2 in the same sequum; or (4) an alteration of material from its original condition in sequums lacking conditions defined in 1, 2, and 3 that obliterates original rock structure, that forms silicate clays, liberates oxides, or both, and that forms granular, blocky, or prismatic structure if textures are such that volume changes accompany changes in moisture.

B_1 A transitional horizon between B and A_1 or between B and A_2 in which the horizon is dominated by properties of an underlying B_2 but has some subordinate properties of an overlying A_1 and A_2.

B&A Any horizon qualifying as B in more than 50 per cent of its volume including parts that qualify as A_2.

B_2 That part of the B horizon where the properties on which the B is based are without clearly expressed subordinate characteristics indicating that the horizon is transitional to an adjacent overlying A or an adjacent underlying C or R.

B_3 A transitional horizon between B and C or R in which the properties diagnostic of an overlying B_2 are clearly expressed but are associated with clearly expressed properties characteristic of C or R.

C A mineral horizon or layer, excluding bedrock, that is either like or unlike the material from which the solum is presumed to have formed, relatively little affected by pedogenic processes, and lacking properties diagnostic of A or B but including materials modified by: (1) weathering outside the zone of major biological activity; (2) reversible cementation, development of brittleness, development of high bulk density, and other properties characteristic of fragipans; (3) gleying; (4) accumulation of calcium or magnesium carbonate or more soluble salts; (5) cementation by such accumulations as calcium or magnesium carbonate or more soluble salts; or (6) cementation by alkali-soluble siliceous material or by iron and silica.

R Underlying consolidated bedrock, such as granite, sandstone, or limestone. If presumed to be like the parent rock from which the adjacent overlying layer or horizon was formed, the symbol R is used alone. If presumed to be unlike the overlying material, the R is preceded by a Roman numeral denoting lithologic discontinuity as explained.

(End of quotation from supplement to Soil Survey Manual, 1962).

The influence of Russian and American ideas has been profound, so their initial broad subdivision of the soil profile into the genetic master horizons appears in many subsequent systems of horizon designation used by other countries. In New Zealand, Taylor and Pohlen (1962) adopted the idea and listed the OABC horizons as masters horizons to which they added a G horizon following the example of Tiurin *et al.* (1959) in Russia. The soil horizon nomenclature working group of the International Society of Soil Science (1967) accepted the basic ABC master horizons as well as the symbols O, G and R although reservations were expressed about the G and R horizons which they thought should technically be called layers. One major innovation which the ISSS working group introduced was the E horizon, restricting the scope of the A horizon as formerly defined, to the surface organo-mineral horizon of soils. The system which appeared in the *Manual Supplement* (1962), was reproduced also in *Soil Taxonomy* (Soil Survey Staff, 1975) as an appendix, although the approach using diagnostic horizons for classification frequently cuts across the ABC system of horizon designations. Despite the quotation that "diagnostic horizons were used in *Soil Taxonomy* to get away from the horizon nomenclature of ABC" (Smith, 1986), the system still flourishes. The US Soil Survey Staff (1981) have produced a (typescript) draft of a new *Soil Survey Manual* in which the O, A, E, B, C, and R master horizons are used, but re-definition of many designations has occurred. A comparison between the old and new systems was published by Guthrie and Witty (1982). The Soil Management and Support Services of the US Department of Agriculture also has produced a summary entitled *Designations for Master Horizons and Layers in Soils* (Department of Agronomy, Cornell, 1986), which also appears as an appendix to *Keys to Soil Taxonomy* (Soil Survey Staff, 1987).

In Volume I, the legend for the *Soil Map of the World* (FAO-Unesco, 1974) the A, E, B, C and R horizons were considered as master horizons. A distinction was made between saturated and non-saturated surface organic layers with the letter H used to denote saturated (peaty) materials and the letter O referred to organic materials which are not normally saturated. The same master horizons were identified in the FAO *Guidelines for Soil Profile Description* (FAO, 1977) and are also used in the revised legend for the *Soil Map of the World* (FAO, 1988).

One persistent feature which emerged from the consideration of the history of development of soil horizon designations is the idea of symbols for surface organic, upper, middle and lower positions in the soil profile; the *master horizon* symbols.

In communications generally, these immediately indicate the broad relationships of an horizon to those adjacent and to the profile as a whole.

Master horizons of organic materials

The designations L (litter), F (fermentation), and H (humus) have been used in Europe for the organic layers of soils since they were introduced by Hesselman (1926). Such organic layers were found on soils which were only saturated for a short period each year. It is necessary to identify these layers on soils before the mor and mull horizons of Muller (1879; 1884) can be identified in the format developed by Heiberg and Chandler (1941) and more fully described by Kubiena (1953).

In the 1951 *Soil Survey Manual*, organic layers were viewed as subdivisions of the A horizon and were not accorded the rank of master horizons. They were designated A_{oo} (litter) and A_o (fermentation and humus horizons).

The organic layers were given master horizon status first in the *Manual Supplement* (Soil Survey Staff, 1962) with the designation O and a subdivision of 01 (litter and upper fermentation layers) and 02 (lower fermentation layer and humus layer). The designations L, F and H have not found as much favour in the USA as they did in Europe. Through the work of Kubiena (1953), the letters F and H were introduced as subscripts to sub- divide the A horizon and then found their way into the systems of horizon nomenclature of Germany, France and Britain. In 1959, Mückenhausen used the A_{oo} and A_o system for the organic layers, but in Die Bodenkunde (1975) he had adopted the symbols A_a for little decomposed organic material and A_h for well-decomposed material. Scheffer and Schachtschabel (1966) replaced the A symbol with O and combined with it subscripts O_f and O_h for fermentation and humus horizons respectively but introduced a new symbol O_i to indicate a litter layer. Blume and Schlichting (1976) suggested retaining the master horizons A, B, C, and proposed the introduction of L, R, G, O, H, and F. The present position the Federal Republic of Germany is given in Bodenkundliche Kartieranleitung (Benzler *et al.*, 1983; Working Group on Soil Systematics, 1985). Litter is designated L, the fermentation layer O_f and the humus layer O_h with peaty materials indicated with H.

In France, a similar gradual evolution of the system has occurred. Initially influenced by Kubiena and subsequently developed by Duchaufour (1970) who indicated the A_{oo} was equivalent to L for litter and A_o for the fermentation F and humus H horizons. The position in France is given by Maignien (1980) who designated organic horizons of freely drained soils by O and peaty, saturated, organic layers by H. O horizons are subdivided into Ol litter, Of fermentation and Oh humus layers and peaty layers have the designations HL for fibric material, HF for mesic and HH for humic materials respectively.

At first, the British Soil Survey adopted the A_{oo} and A_o symbols of the US 1951 *Manual* but these gave way to the L, F and H symbols, leaving the A for the surface organo-mineral horizon only. The current position in England and Wales is given by Avery (1980) which maintains the L, F and H designations for well-drained soils and uses the letter O with O_f fibric, O_m mesic and O_h humic for normally saturated peats.

As a result of changes in the designations for organic horizons in the draft for the new US *Soil Survey Manual* (Soil Survey Staff, 1981) only one master horizon is required for organic materials. It is defined as follows:

O horizons or layers: Layers dominated by organic material, except limnic layers, that are organic. Some are saturated with water for long periods or were once saturated but are now artificially drained; others never have been saturated.

Table 6 Recognised Master Horizons from several schemes of Horizon Designations

Source	Organic horizon free	sat.	subaq.	Mineral horizons	Additional
Soil Survey Staff USA (1951)	(Ao)			A B	R
Tiurin *et al.* USSR (1959)	(Ao)	(AT)		A B C	R D
Whiteside (1959)	O			V E I P U	R G X S Z
Soil Survey Staff USA (1962)	O			A B C	R
Taylor & Pohlen (1962)	O			A B C	
ISSS Committee (1967)	O			A E B C	R G K
FAO-Unesco (1974)	O	H		A E B C	R
FAO Guidelines (1977)	O	H		A E B C	R
Soil Survey Staff USA (1975)	O			A B C	R
Canada (1978)	LFH	O		A B C	R W
Maignien France (1980)	O	H		A E B C	R G K S
Avery (SSEW) (1980)	LFH	O		A E B C	R G
Soil Survey Staff USA (1981)	O			A E B C	R
Fridland USSR (1982)	O	T		A EL B C	MD G GO IPMR KSL AO
McDonald (Aust) (1984)	LFH	O		A B C D	R
Germany (1985)	LO	H	F	A B C P	G T S MY
SMSS (1986)	O			A E B C	R
New Zealand (1986)	O			A E B C	R

Reviewing the areas of agreement and disagreement in the master horizons assigned to the organic part of the soil profile, it is apparent that there is no great divergence of opinion. The symbol O is used widely for those organic horizons which are not permanently saturated. The only systems which do not specifically use the O master horizon in this sense are those of England and Wales, Canada and New Zealand where the symbols L, F and H are used instead. These countries have chosen the letter O as a master horizon symbol to designate those organic horizons which are saturated, ie. peaty organic layers. This is rather confusing and is out of step with the many other systems used throughout the world. Organic horizons are not so common in Australian conditions, but McDonald *et al.* (1984) have chosen to use O for normal organic horizons and P for saturated peaty organic layers. The 1982 system outlined in Bodenkundliche Kartieranleitung for Germany suggested F for sub-aqueous humus accumulation. This is confusing as the use of F has been widely applied to the fermentation horizon in the past, and especially as they have retained the use of L for litter. Whiteside's (1959) suggestions did not dwell greatly on the organic horizons, which he designated O; and Fridland's (1982) scheme advocated T for the saturated peaty organic layers.

Master horizons for mineral soils

There is greatest agreement about the designation of the A horizon. Except for Whiteside's suggestion of V, virtually all who use a genetic or morphological system use the letter A for the surface organo-mineral horizon.

Where there is grave disagreement is in the application of the symbol E for the subsurface leached horizon. Some have followed tradition and used A_2 or substituted A_e for it and hence see no need to use the E symbol. Others, now a majority, have limited the scope of the definition of the A horizon by the introduction of the E horizon as a master horizon; this includes the USA where the E horizon has been introduced in the draft for the 1981 *Soil Survey Manual*. The current exceptions are the Australian, Canadian and German systems, the last mentioned now use the E (for esch) symbolising a surface horizon enriched by plaggen additions. The difficulty in Australia is that many soils do not have less clay or lower sesquioxides levels in the A_2 compared with the A_1 and so it is thought inappropriate to designate such horizons as eluvial.

The concept of the B horizon as a master horizon, lower in the soil profile also has general acceptance. The use of subscript symbols to distinguish the range of lower horizons present in soils is widespread. Within recent times, Whiteside (1959) is the only one to suggest an alternative symbol and that is I (for illuvial), but this has not been found acceptable in the face of the widely established use of the letter B. Discussion of the many and varied subscripts used with B horizons follows in a later section but one of the first subdivisions of the B horizon was by Laatsch (1938) who introduced the symbol (B) for a non-illuvial B horizon resulting from weathering *in situ*. This symbol was subsequently adopted by Kubiena (1953) and now has been superceeded by the use of subscript letters (usually w).

In the draft for the 1981 US *Soil Survey Manual* the concept of a B horizon rests in part on its position below an A, E or O horizon, that all or much of the original rock structure is obliterated, and that it is dominated by one or more of: illuvial concentrations, removal or addition of carbonates or gypsum, presence of residual concentrations of sesquioxides, sesquioxide coatings and alterations that form silicate clays or liberate oxides or both, or prismatic structure resulting from volume changes caused by differences in moisture content.

The symbols C, D and R are all used to signify the parent material or other layers beneath the solum. There is general agreement about the use of C as a symbol for the parent material, even though it is not always possible to be certain that the underlying material was similar to that from which the soil has formed. Only Whiteside's P for primary material differs from the other systems where C is acceptable, he also suggests a U (for unrelated) for materials which are obviously different from the material which formed the soil parent material. The symbols D and R have both been used to designate a rock layer below the soil profile which may affect its genesis and performance. Although used in the 1951 US *Soil Survey Manual*, the symbol D has since fallen from favour in the soil horizon designation systems reviewed, including the 1981 draft for the new US *Soil Survey Manual* where C horizons, little affected by pedogenetic processes essentially lack the properties of O, A, E, or B horizons. Only the Australian system still retains D for unrelated material below the genetic horizons. However, there is again unanimity about the use of R as a rock layer except for the German system which uses a P for material with more than 45 per cent clay, shrink-swell properties and prismatic or polyhedral structures in material which give rise to pelosol soils. This leaves the symbol R (for rigolen) free for use to designate soil materials which have been deeply cultivated.

Predictably, it is with the use of the remaining master horizon symbols that the greatest divergencies arise. In this group of designations, the letter G has the most support. It has found favour in the USSR, Britain France and Germany as a master horizon, but the ISSS Committee queried its use in 1967. It has never found much support in the USA, and the Canadians have introduced a W symbol for saturated materials. The German system distinguished between the G horizon (true gley) and the S horizon (Pseudogley) and Fridland (1982) made a similar distinction using G and GO.

Resulting from work by Gile *et al.* (1965, 1966, 1981), the ISSS Committee (1967) considered the possible introduction of a K horizon but the French system of Maignien (1980) has been the only one to accept fully this suggestion, the other systems dealing with carbonate accumulation with subscripts to the B or C horizons.

Gile *et al.* (1965) proposed the K horizon (German Kalk) as a new master horizon which has a "fine grained authigenic carbonate" fabric occurring "as an essentially continuous medium. It coats or engulfs, and commonly separates and cements skeletal pebbles, sand and silt grains". "The K horizon contains 90% or more by volume of K-fabric in its most prominent subhorizon (K2) and 50 per cent or more of K-fabric in upper and lower transitional horizons (K_1 and K_3)". The K horizon is so strongly impregnated by carbonates that its morphology is dominated by their presence.

The very detailed system of horizon nomenclature adopted in Bodenkundliche Kartieranleitung (Benzler *et al.*, 1983; Working Group on Soil Systematics, 1985) has several other symbols which must be considered the equivalent of master horizons. The use of P and S has already been commented upon. The letter T has been applied to the solution residue from carbonate rocks, similar to the W of Whiteside (1959). M is used to designate alluvial or colluvial accumulations of pedologically altered material and Y to designate materials of anthropological origin such as rubble, domestic waste and industrial waste.

In his review of the state of the art Whiteside (1959) made several suggestions for master horizons which he hoped would lead to less confusion. These suggestions followed the accepted ABC tradition but they have not been incorporated into any of the current working systems. He suggested the letter R be used for the concept of sesquioxides *in situ* as resistant weathering products left after the hydrolysis and solution of silica. Z was suggested for the concentration of a weathering product which included clay minerals and W for water-leached materials where changes occurred *in situ* but which did not include illuvial silicate clay accumulation, sesquioxides or organic matter (embracing the (B) or B_w concept). Horizons with an unknown genesis Whiteside suggested could be designated X and those enriched with salt S.

The final contribution to master horizon designations during the last few years is Fridland (1982) who followed the German approach and designated a ground-water gley as GO and surface-water or pseudogley as S. The takyr crust of light-coloured vesicular material he suggested could be K and the laminated layer beneath could be L. Horizons where salt accumulation had taken place could be S. Fridland also elevated the cultivation layers to master horizon status with P for a normal cultivation horizon, M where deep ploughing has occurred and R where fill (made ground) forms the substrate below the soil.

Two kinds of transition horizon are identified by the 1981 US *Soil Survey Manual* draft, these are where the properties of one master horizon are overlain by properties of another throughout the transition zone in which case the convention AB, EB, or BC may be used. The other situation arises where substantial parts of an horizon enclose parts characteristic of another horizon; in this case the designation E/B or B/C may be used.

SUBDIVISION OF THE MASTER HORIZONS AND LAYERS

Throughout the history of soil science there has been a steady trend towards a closer definition of horizons in systems of horizon designation. This has taken two forms. An earlier approach using subscript numbers was employed widely until the middle of the present century, but thereafter a system using lower case letters, often the initial letter of the feature being emphasised, has gained in popularity (e.g. t = clay enrichment, German ton = clay or s = sesquioxide enrichment).

Subdivision using numbers

In the discussion of the master horizons it was shown that by the 1950s it was thought desirable to subdivide using the symbols A_1 A_2 A_3, B_1 B_2 B_3 to distinguish different features or gradational situations. This system was adopted in the USA and is described fully in the 1951 *Soil Survey Manual*. In the USSR the comparable publication which assembles the information required for the mapping and classification of soils during the first half of the twentieth century is *Pochvennia Syemka* (Tiurin *et al.*, 1959). This also describes the subdivision of the master horizons into A_1 A_2 A_3 etc. As a result of these publications, the ABC system with master horizons and numerical subdivisions is well known and has been widely used throughout the world. As an example, the Canaseraga series is given in the 1951 US *Soil Survey Manual* to illustrate the method of soil description and application of the horizon designations used at that time. The profile description is reproduced as it was printed in the *Soil Survey Manual.*

Canaseraga very fine sandy loam - virgin:

A_o Matted mor humus layer; pH 4.0-4.5. 2 to 4 inches thick.

A_1 0 to 1 inch, dark greyish-brown (10YR 4/2) very fine sandy loam with weak fine crumb structure; very friable; white flecks of an incipient bleicherde may occur; pH 4.5-5.2. ½ to 2 inches thick.

B_{21} 1 to 8 inches, yellowish-brown (10YR 5/6) very fine sandy loam with weak fine crumb structure; very friable; some stone fragments; pH 5.0-5.4. 5 to 10 inches thick.

B_{22} 8 to 18 inches, yellowish-brown (10YR 5/4) very fine sandy loam with weak medium crumb structure; friable; some stone fragments; pH 5.0-5.4. 8 to 12 inches thick.

B_3 18 to 26 inches, light yellowish-brown (10YR 6/4) fine sandy loam or loam with weak coarse crumb structure; friable; some stone fragments; pH 5.2-5.6. 7 to 12 inches thick.

C_1 26 to 80 inches, pale-brown (10YR 6/3) to light brownish-grey (10YR 6/2) silt loam or loam with moderate numbers of gravel and stone fragments; weakly coarse platy; firm to very firm and moderately compact in place; large roots penetrate this horizon; pH increases from 5.5 at the top to about 6.5 at the bottom. 40 to 80 inches thick.

C_2 80 inches +, material similar to horizon C_1 but near neutrality; pH increases slightly with depth and weakly calcareous material may occur at depths greater than 12 feet. Commonly some stratification is apparent.

In this profile, the superficial organic materials are designated A_o, although it is described as mor and so probably contains litter, fermentation and humus layers. The A1 is stated to include bleached material and the B horizon is subdivided according to the convention B_{21} and B_{22}. No identifiable A_3 or B_1 was present, however a B_3 transitional to the C_1 is described. A C_2 horizon of a calcareous nature is the lowest horizon described.

The Russians continued to use the basic ABC system of horizon designation with numerical subscripts until recently and their current system is demonstrated by Egorov *et al.* (1977, translated 1987). Unfortunately this book does not give a consolidated list of soil horizon designations with definitions, but two of the profile descriptions from it illustrate the most recently available indication of the use of the system in the USSR.

<u>Podzolic soils</u>

The most complete set of horizons characteristic of some virgin forest soils includes the following:

$$A_o - A_oA_1 - A_1 - A_1A_2 - A_2 - A_2B - B(B_1,B_2) - BC - C$$

A_o Forest litter in the form of felt, semi-decomposed peaty layer or weakly decomposed litter. Thickness from a few millimetres to 7-10 cm.

A_oA_1 Transitional organomineral horizon retaining the structure and properties of the forest litter. Thickness from 0.5 to 2 cm.

A_1 Humus horizon of light grey, grey and occasionally dark grey showing powdery or weak cloddy-powdery structure. Thickness quite variable, from 1-2 to 12-15 cm and more.

A_1A_2 Eluvial accumulation subhorizon, grey, light grey, whitish grey often with pale yellow shades, lighter coloured than A1, powdery, indistinctly laminar, rarely weak crumb-powdery. Thickness usually not exceeding 5-10 cm.

A_2 Podzolic horizon, the lightest coloured in the profile (white, light grey, at times pale yellow); structure platy, scaly-platy or leafy; the horizon may also be structureless. Thickness from 1 to 20 cm or more.

A_2B Transitional eluvial-illuvial (illuvial podzolized) horizon. Usually coloured brownish or reddish. Mottled with abundant spots of SiO_2 and light coloured tongues permeating from A_2 horizon. Structure is weak nutty or nutty-platy. Thickness rarely exceeding 10-15 cm.

B Illuvial horizon, usually the most compact and intensely coloured. Thickness has a fairly wide range - from 10 to 100 cm or more. This horizon is divided into two subhorizons; B_1 and B_2.

B_1 Brown, cinnamon brown or reddish brown, dense nutty (coarse nutty or nutty-cloddy). The pod faces have cinnamon brown coatings with spots of white. Thickness 20-30 cm. Gradual boundary with the subhorizon below it.

B_2 Colour similar to that in B_1 but at times lighter. prismatic or nutty-prismatic with fewer spots of silica. Downward the structure becomes coarser. Very gradual boundary with the horizon below. Thickness 30-50 cm.

BC Transitional horizon, less dense (coarse prismatic or lumpy-prismatic), abrupt boundary with the parent rock.

C Soil-forming rock, weakly altered or unaltered by soil formation. Thickness of soil profile highly variable - from some tens of centimetres to 2.5 m or more.

Chernozems

The soil profile has the following organisation:

$$A - AB - B(B_t, B_{ca}) - C_{ca} - (C_{gp})$$

A humus-rich horizon, homogeneously dark with granular structure.

AB humus-rich horizon, dark with general increase in brown tones downward or nonuniformly coloured with alternation of dark humus-rich parts and dark brown, greyish cinnamon brown spots or wedges, but with the dark humus colouration dominant. Usually has a granular structure.

B horizon transitional to the parent material, is primarily brown with gradual or nonuniform tongue-like and other forms. Humus enrichment is less with depth. According to the degree and form of humus enrichment and the structure, the horizon may be subdivided into B_1 and B_2 subhorizons; but in many subtypes further division of the horizon into clay-enriched (B_t) or illuvial-calcareous (B_{ca}) subhorizons is also done. Concentration of carbonates is observed further down, in the BC_{ca} horizon and the parent material (C_{ca}). In certain southern subtypes, horizons show an accumulation of gypsum (C_{gp}).

The lower boundaries of both A and AB horizons are demarcated on the basis of the predominance of humus colouration.

Subdivision using lower case letters

At the time of the compilation of the 1951 *Soil Survey Manual*, it was accepted that letter subscripts "may be helpful in indicating processes that have been active within a horizon or layer". The following were suggested:

b A subscript to add to the genetic designation of a buried soil horizon. Thus beneath one solum, or part of one, buried horizons are designated as A_{1b}, B_{2b}, and so on.

ca An accumulation of calcium carbonate, as in D_{ca} or B_{3ca}.

cn Accumulations of concretions rich in iron,iron and manganese, or iron and phosphate (like perdigons, for example, or the 'shot' in some soils of the Pacific Northwest).

cs An accumulation of calcium sulphate (gypsum), as in D_{cs}.

f Frozen soil, as C_f under Tundra.

g A gleyed (glade) horizon, as B_g or B_{3g}.

h* Outstanding accumulation of decomposed organic matter for the horizon, as in the B_2 of a humus Podzol, making it B_{2h}.

ir* Outstanding accumulation of finely disseminated iron for the horizon, as in the B_2 of an iron Podzol, making it B_{2ir}.

m A subscript (suggesting 'massive') for indurated horizons composed mainly of silicate minerals, such as fragipans, within the solum or beneath it, which are indurated much more than horizons normally having the principal horizon designation given. Such an indurated horizon is given its appropriate designation, such as B, B_2, C, or G, and then the subscript is added to form B_m, B_{2m}, C_m, or G_m.

p Indicates ploughing or other disturbance, especially of the A horizon.

r A subscript applied to a D layer of hard rock like that from which the C has developed.

sa An accumulation of soluble salts, other than calcium carbonate or calcium sulphate.

t* Outstanding accumulation of clay for the horizon, as in the B_2 horizon of podzolic soil richer in clay than the B_2 horizon of the associated normal soil, making it B_2t (from ton - clay in German).

u Unconformable layer with inherited characteristics unlike those of the adjacent soil material, such as a stone line within a B horizon, making it B_{3u}.

* only used with B horizon.

It was further explained that these symbols did not provide for all situations and the problem of plaggen additions to the surface of some soils was noted, as was the possibility of using an for man-made anthropic layers. In his Soils of Europe, Kubiena (1953) suggested the use of a number of lower case subscripts in association with the letters designating the master horizons. The B horizon of podzols could be designated "by the preponderance of the particular kind of illuvial material concentrated in them", e.g. Bs for sesquioxide-enriched horizons and Bh for humus-enriched horizons following the suggestion of Palmann and Haffter (1933). The symbol (B) was proposed by Kubiena for an horizon which is not an enriched horizon of illuviated substances, but has been developed by the weathering and oxidation of iron complexes. He also suggested Ae as a more informative symbol than A_2 for the eluvial horizon of podzols (Figs. 8 and 9).

Appreciating that there was already considerable confusion in soil horizon designation schemes, Whiteside (1959) proposed a complete re-appraisal of the system and advocated letter subscripts using all but three of the letters of the alphabet:

a concentration of alkali soluble, mineral, cementing materials, insoluble in water.

b concentration of hydrated aluminium oxides or hydroxides (from bauxite).

c cemented, consolidated, or indurated even when moist. In the W, P and U horizons this is the result of non-pedogenetic processes (ie. it is inherited from the primary material while in the other horizons it is the result of pedogenetic processes unless otherwise stated).

d accumulation of undecomposed, dead, organic material (from duff) in which the organic structures are clearly visible (includes A_{oo} of *Manual*, L of forest soils, root mats, and some peaty layers of organic soils).

e (not yet assigned).

f accumulation of partially decomposed plant material (fermentation layer) (includes F layers of forest soils and some peaty layers of organic soils).

g (not yet assigned).

h concentration of decomposed organic matter (from humus) in which very few or no plant structures are recognisable (includes H layers of forest soils and some A_o layers of *Manual*, mucky layers of organic soils, O_h; mineral layers in which humus has been concentrated by formation *in situ*, V_h and V_{hp}, or by illuviation, I_h).

i concentration of iron oxides, usually finely disseminated.

j for layers whose characteristic properties are weakly developed (from juvenile).

k accumulation of calcium carbonate (from kalk, in various languages, as suggested by Mückenhirn *et al.*, 1949 (includes ca of *Manual*).

l (use of this symbol has been purposely avoided because of the danger of confusion with the arabic numeral 1 in typing).

m residual concentrations of minerals from the primary material (from mother).

n concentration of sodium (from natrium) as exchangeable ion or carbonate.

o reserved for oxidation zone if needed in addition to GI, IG, EG, G, etc. Possibly o and r may be useful for designating the relative proportions of the year that oxidising and reducing conditions exist in a soil horizon, as indicated by redox, oxygen, or ferrous-iron determinations.

p when following the main-horizon letters = ploughed or other layers whose properties have been strongly influenced by man's activities (includes an and p of Manual).

when preceding the main-horizon letters = buried or exhumed paleosols; layers having characteristics inherited at least in part from a previous geologic time interval (ie. preceding that represented by the present geomorphic surface beneath which it is located). This letter precedes the capital letter but follows the roman numeral if present. (This differs from the suggestion of Ruhe and Daniels (1958) in the use of a small letter instead of a capital letter and includes b of *Manual*.)

q quasi-cemented, relatively compact layer that is dense, hard or very hard and apparently cemented when dry, brittle when moist, and composed mainly of quartz and silicate minerals, eg. fragipans. Indurated much more than horizons normally having the horizon designations, but not cemented or consolidated or resistant to strong deformation forces when moist.

r when following the main-horizon letter = reserved for reduction horizon, indicating a reducing milieu in the respective horizon by grey, grey-green, or grey-blue colours. May be needed only with G, to free the capital letter for all subhorizons collectively or as suggested under o above.
when preceding the main-horizon letter = relict from earlier conditions that no longer exist. Can apply to characteristics associated earlier with the present land surface as well as with paleosols.
s accumulation of water-soluble salts (from Latin *sal* = salt), other than calcium carbonate, dolomite or calcium sulphate (includes sa layers of *Manual*, and Sa layers of Kubiena).
t concentration of clay minerals (from English *texture* or German ton).
u unconsolidated, uncemented materials relatively unaltered by weathering and other soil forming processes. Probably needed only in the P and U horizons, other subscripts would make it unnecessary in other horizons which are assumed to be unconsolidated unless otherwise noted.
v for layers whose characteristic properties are prominently developed (from vigour).
w water-containing or -storing layers.
x (not yet assigned).
y accumulation of calcium sulphate (from Spanish yeso' gypsum, after Kubiena).
z for layers permanently below the freezing point of pure water 0°C (from zero).

These proposals by Whiteside produced discussion and comment at the time but they have not been acted upon directly. However, a working group of the International Society of Soil Science subsequently met to discuss the subject of horizon designations and a brief report was published in the ISSS Bulletin No. 31 in 1967, and presented to the 9th International Congress of Soil Science at Adelaide, Australia in 1969. The committee recommended 20 subordinate symbols to be used in conjunction with the master horizons to give greater precision to the morphology of the horizon. The proposed suffixes are:

a (from German Anmoor, peaty) well decomposed organic matter accumulated under hydromorphic conditions; used with the A horizon (for instance A_a).
b buried; applied to buried horizons (for instance, A_{1b}; B_{tb}).
ca accumulation of calcium carbonate (for instance, C_{ca}).
cn accumulation of concretions or hard non-concretionary nodules enriched in sesquioxides (for instance, B_{2ox}).
cs accumulation of calcium sulphate (for instance, C_{cs}).
f fermented, partly decomposed organic matter; applied to the O horizon (for instance, O_f).
fe illuvial accumulation of iron; applied to the B horizon of Podzols (for instance, B_{2fe}).

g strong mottling reflecting variations in oxidation and reduction as a result of periodical wetness (for instance, B_{2tg}, C_g). (See also note made with reference to the G horizon.)

h humified, well decomposed organic matter; applied to:
1) the lower part of the O horizon (for instance O_h);
2) an undisturbed A horizon (for instance, A_h);
3) the illuvial accumulation of organic matter in the B horizon of Podzols (for instance B_{1h}) or in B horizons formed in peat (for instance B_{oh}).

m strong cementation or induration (for instance, B_{tm}).

na high percentage of sodium in the exchange complex; applied to the B horizon of Solonetz soils (for instance, B_{tna}).

o poorly decomposed organic material accumulated under hydromorphic conditions; applied to peats (for instance, C_o).

ox residual accumulation of sesquioxides; applied to the B horizon of Latosols or Ferralitic soils or Oxisols (for instance, B_{ox}).

p disturbed by ploughing or other tillage practices; applied to the A horizon (for instance, A_{1p}).

r concretionary or gravelly layers (for instance, B_{oxr}).

sa accumulation of salts more soluble than gypsum (for instance, B_{sa}, C_{sa}).

t (from German Ton, clay) illuvial accumulation of clay; applied to B horizons (for instance B_t).

v (from German Verwitterung, weathering) accumulation of clay by alteration *in situ* (for instance, B_v).

x fragipan (for instance, B_x, B_{vx}, B_{tx}).

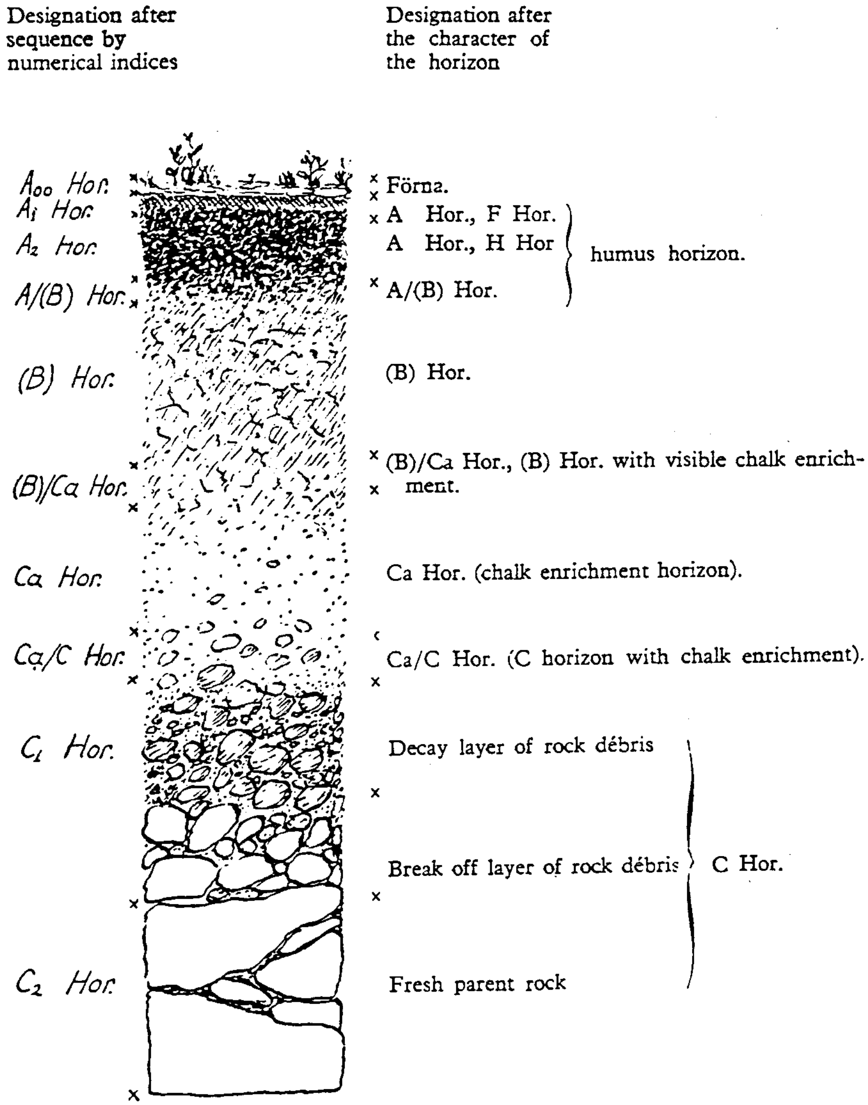

Fig. 8 Profile Diagram for Soils of the Brown Earth Region (Kubiena, 1953)

Note: Furthermore can be distinguished: (A) horizons with raw soils; (B)/C horizons with chalk deficient soils; G, (B)/C and G/C horizons with gleyisation of the subsoil; and g horizons with gley-like soils.

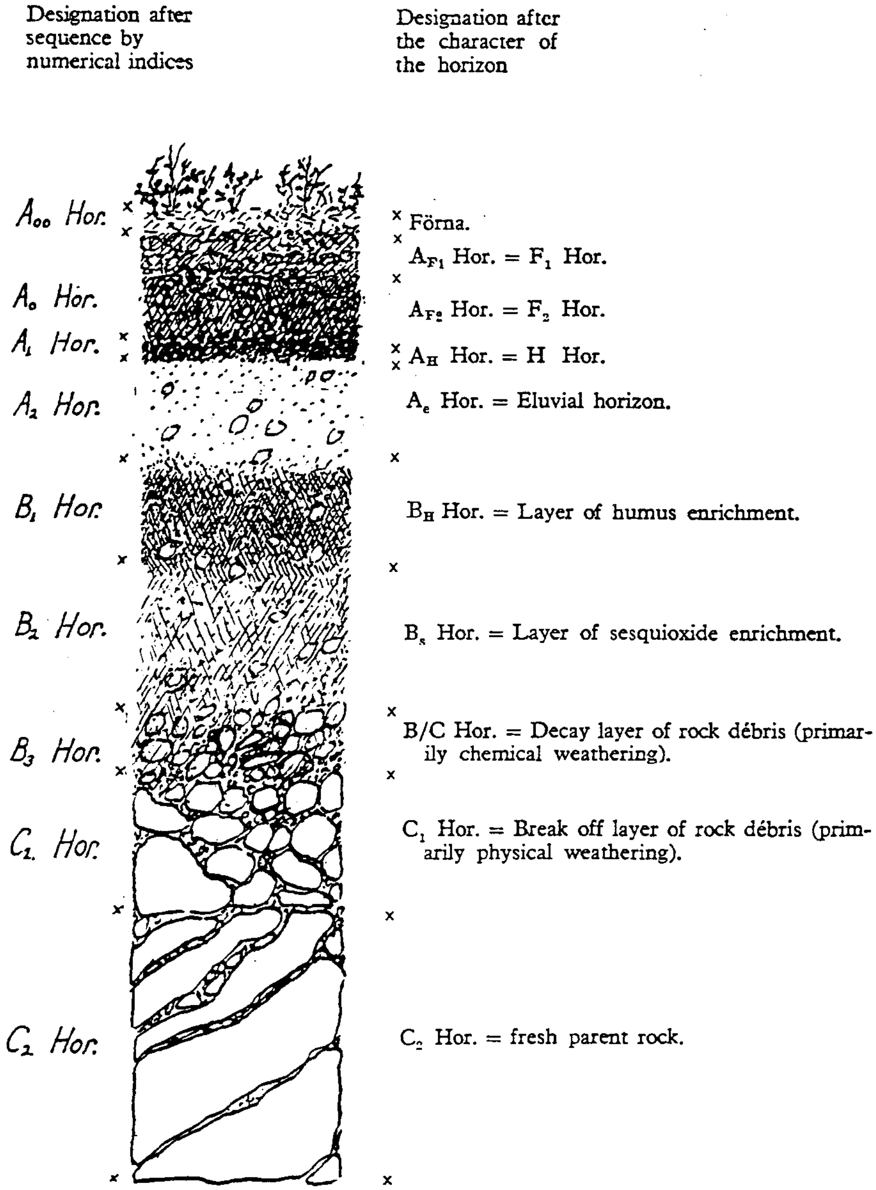

Fig. 9 Profile diagram for soils of the Podzol Region (Kubiena, 1953)

The committee received a suggestion that the suffix v should be changed to s as French pedologists already use the v suffix for vertic features. The suggestion does not seem to be taken up by later systems of horizon nomenclature.

The Advisory Panel which prepared the FAO-Unesco *Soil Map of the World* stated in the legend (Volume I) that "though the ABC horizon nomenclature is used by the great majority of soil scientists the definition of these designations and their qualification with suffixes or figures vary widely". They produced a list of acceptable letter suffixes, developed from the ISSS proposals, which are used to qualify the master horizon symbol in the soil descriptions contained in the text of the 9 volumes accompanying the maps. The symbols are as follows:

- b Buried or bisequal soil horizon (for example, B_{tb}).
- c Accumulation in concretionary form; this suffix is commonly used in combination with another which indicates the nature of the concretionary material (for example, B_{ck}, C_{cs}).
- g Mottling reflecting variations in oxidation and reduction (for example, B_g, B_{tg}, C_g).
- h Accumulation of organic matter in mineral horizons (for example, A_h, B_h); for the A horizon, the h suffix is applied only where there has been no disturbance or mixing from ploughing, pasturing or other activities of man (h and p suffixes are thus mutually exclusive).
- k Accumulation of calcium carbonate.
- m Strongly cemented, consolidated, indurated; this suffix is commonly used in combination with another indicating the cementing material (for example, C_{mk} marking a petrocalcic horizon within a C horizon, B_ms marking an iron pan within a B horizon).
- n Accumulation of sodium (for example, B_{tn}).
- p Disturbed by ploughing or other tillage practices (for example, A_p).
- q Accumulation of silica (C_{mq}, marking a silcrete layer in a C horizon).
- r Strong reduction as a result of groundwater influence (for example, C_r).
- s Accumulation of sesquioxides (for example, B_s).
- t Illuvial accumulation of clay (for example, B_t).
- u Unspecified; this suffix is used in connection with A and B horizons which are not qualified by another suffix but have to be subdivided vertically by figure suffixes (for example, A_{u1}, A_{u2}, B_{u1}, B_{u2}). The addition of u to the capital letter is provided to avoid confusion with the former notations A_1, A_2, A_3, B_1, B_2, B_3 in which the figures had a genetic connotation. If no subdivision using figure suffixes is needed, the symbols A and B can be used without u.
- w Alteration *in situ* as reflected by clay content, colour, structure (for example, B_w).
- x Occurrence of a fragipan (for example, B_{tx}).
- y Accumulation of gypsum (for example, C_y).
- z Accumulation of salts more soluble than gypsum (for example, A_z or A_{hz}).

When needed, i, e and a suffixes can be used to qualify H horizons composed of fibric, hemic or sapric organic material respectively.

At this stage of development, certain combinations of letters and associated processes were becoming widely accepted and the FAO *Guidelines for Soil Profile Description* (1977) were drawn up using the same list of subscripts as used in the legend of the FAO-Unesco *Soil Map of the World*. Enquiries have shown that many countries now utilise these guidelines for their descriptions including the designations given to soil horizons.

When the selection of profiles was made to illustrate the *Soil Map of the World*, there was, unfortunately, little possibility of standardising the soil horizon designations of the wide range of profiles used. As an example of the system a Ferric Luvisol from Senegal (a leached tropical ferruginous soil with mottles and concretions), is reproduced to illustrate the use of the system.

A_{p1} 0-6 cm Grey-brown (Munsell 5YR 5/3); humus-bearing; sandy texture; fine nuciform; poor compactness; good internal drainage; tubular porosity; many roots and insect tunnels.

A_{p2} 6-13 cm Light grey-brown (5YR 6/2); slightly clayey sand texture; fine to blocky nuciform; always a certain organic richness; higher average compactness than the previous horizon; good porosity, many roots.

E 13-31 cm Yellowish beige (5YR 6/4); again very slightly humus- bearing; slightly clayey sand texture; nuciform; macroporosity due to roots and insects; moderate to strong compactness.

B_t 31-79 cm Darker beige to reddish yellow (5YR 8/4); sandy clay to clay texture; definite clay accumulation; blocky; fairly strong compactness; low to medium porosity; fine tubular type.

B_{tg} 79-117 cm Beige-yellow (5YR 7/6); sandy clay texture; nuciform to blocky; moderate compactness; incipient individualisation of well demarcated red ironstone mottles.

B_{cs} 117-150 cm Beige (5YR 8/4)matrix colour, variegated red and ochre; sandy clay texture; coarse blocky; moderate compactness; poor to medium ped porosity; plentiful patches and concretions of medium to poor hardness and red to dark red and more rarely dark purple in colour. Near the bottom the ochre mottles become gradually larger with slightly hardened concretions having a slightly hardened ochre centre.

C_g 150 cm Continuous variation; texture with beige matrix; appearance of light grey mottles without distinct boundaries; very numerous concretions of dominant red or rust colour; some can be crushed between the fingers, leaving a harder central point; structure tending toward blocky; moderate to strong cohesion.

In the USA, the re-drafting of the *Soil Survey Handbook* provided an opportunity to have a fresh look at the existing subscript letters which had been in use from the time of the 1962 Supplement to the 1951 *Soil Survey Handbook*. As a result several changes have been made to the designations for special kinds or special features of master horizon. Full details of each designation symbol are given in the draft *Soil Survey Handbook* (Soil Survey Staff, 1981), but in the present context it is sufficient to state that the symbols b,f,g,h,m,p,r,t and x retain the same meaning as before. Symbols which have been changed are c (formerly cn), k (ca), n (sa), q (si), s (ir), y (cs) and z (sa). New symbols, a, e, i, o, v, and w have been introduced to provide detail for organic horizons, residual sesquioxides, plinthite and a colour/ structure B. The full list is as follows:

a highly decomposed organic material
b buried genetic horizon
c concretions or hard nonconcretionary material
e organic material of intermediate decomposition
f frozen soil
g strong gleying
h illuvial accumulation of organic matter
i slightly decomposed organic material
k accumulation of carbonates
m cementation or induration
n accumulation of sodium
o residual accumulation of sesquioxides
p ploughing or other disturbance
q accumulation of silica
r weathered or soft bedrock
s illuvial accumulation of sesquioxides and organic matter
t accumulation of silicate clay
v plinthite
w development of colour or structure
x fragipan character
y accumulation of gypsum
z accumulation of salts more soluble than gypsum.

One or two of these suffixes, rarely three, may be attached to the symbols for the master horizons to indicate the presence of a special character; p is only used for surface horizons and when more than one suffix is used the following letters are written first: a, e, i, h, r, s, t, v and w. Suffixes h, s and w are not used with g, k, q, y, z, or o, and where they are used, suffixes c, f, g, m, and x are written last.

Whilst most of these symbols have retained a common thread to their meaning, it is worth pointing out that the definition of the suffix t has been changed substantially from an emphasis on illuvial clay accumulation to include also those soils where a clay increase in the B horizon is caused by other processes.

After detailed examination of a toposequence of soils in Brittany, Roussel (1980), quoting a paper by Aurousseau *et al.* (1979), has used a system of horizon designations based upon an interpretation of the profile morphology and mineralogy of the horizons. Thus, an horizon where muscovite mica is being transformed to kaolinite and in which there are eluvial characters present, is designated ALE. Horizons where there is eluviation and loss of iron and its redistribution are designated EG and with evidence of illuvial accumulation of clay and a platy structure XG. Combinations of eluviation and degradation are designated by ED, a blocky structure with clay illuviation and degradation BD and fragic character with illuvial clay accumulation and degradation is recorded as XD.

Using this nomenclature, a wider range of horizons found in forested soils of Brittany is provided by Aurousseau (1985) and Algeria by Lahmar, Arrousseau and Bresson (1989). By means of colour, disposition and structure, 23 different horizons have been identified in Brittany and their relationship to each other is diagrammatically shown in Table 7. Girard (1989) has demonstrated how such horizons may be mapped using their thickness, contrast and composition.

Soil Layers

Two main concepts of soil layers appear in soil science. The first is concerned with the traditional names given to horizons or groups of horizons such as are described in the Manual and the supplement (Soil Survey Staff, 1951, 1962). The second concept deals with materials occurring at or near the earth's surface which are present as layers, more or less parallel to the surface, which have resulted from biological or geological, not soil forming, processes.

In the section describing soil horizons, the wording of the 1951 US *Soil Survey Manual* was not very definite in its distinction between soil layers and soil horizons. In the case of organic materials upon the surface, it stresses the variation which can occur as a result of fire and cultivation, making these difficult to interpret as horizons. The C horizon however, is stated to be a layer in a definition which begins: "The C horizon is a layer of unconsolidated material ...." A footnote explains this further: "Although commonly used and understood the C is not strictly a soil horizon as herein defined, partly because it is little modified by biological processes in soil formation, and partly because it often has an undetermined lower limit." However, when describing the D layer (consolidated parent rock), there is no doubt as it is described as a layer and not a soil horizon, but in the 1962 Supplement, the material formerly designated D was included in the C, leaving the symbol R for "underlying consolidated bedrock".

Kubiena (1953), in *The Soils of Europe*, refers to the organic materials at the soil surface as layers, and proceeds to use the term as a subdivision of horizons; his L F and H layers making subhorizons in the same manner as the A1 and A_e form the mineral layers of the A horizon. Interest in palaeosols and the recognition in many parts of the world of successive phases of soil formation on former land surfaces has helped to focus attention on the problem of layering in soils. In some cases this amounts to no more than a colluvial thickening in the A horizon, but other examples, especially in loess and alluvial materials, may include complete buried profiles or parts of profiles. In simple cases the use of the lower case b (either before or after the symbol for the master horizon) is sufficient to denote buried horizons,

Table 7 Relationships of soil horizons recognised in 'the soils of the forest of Brittany' (Aurousseau, 1975)

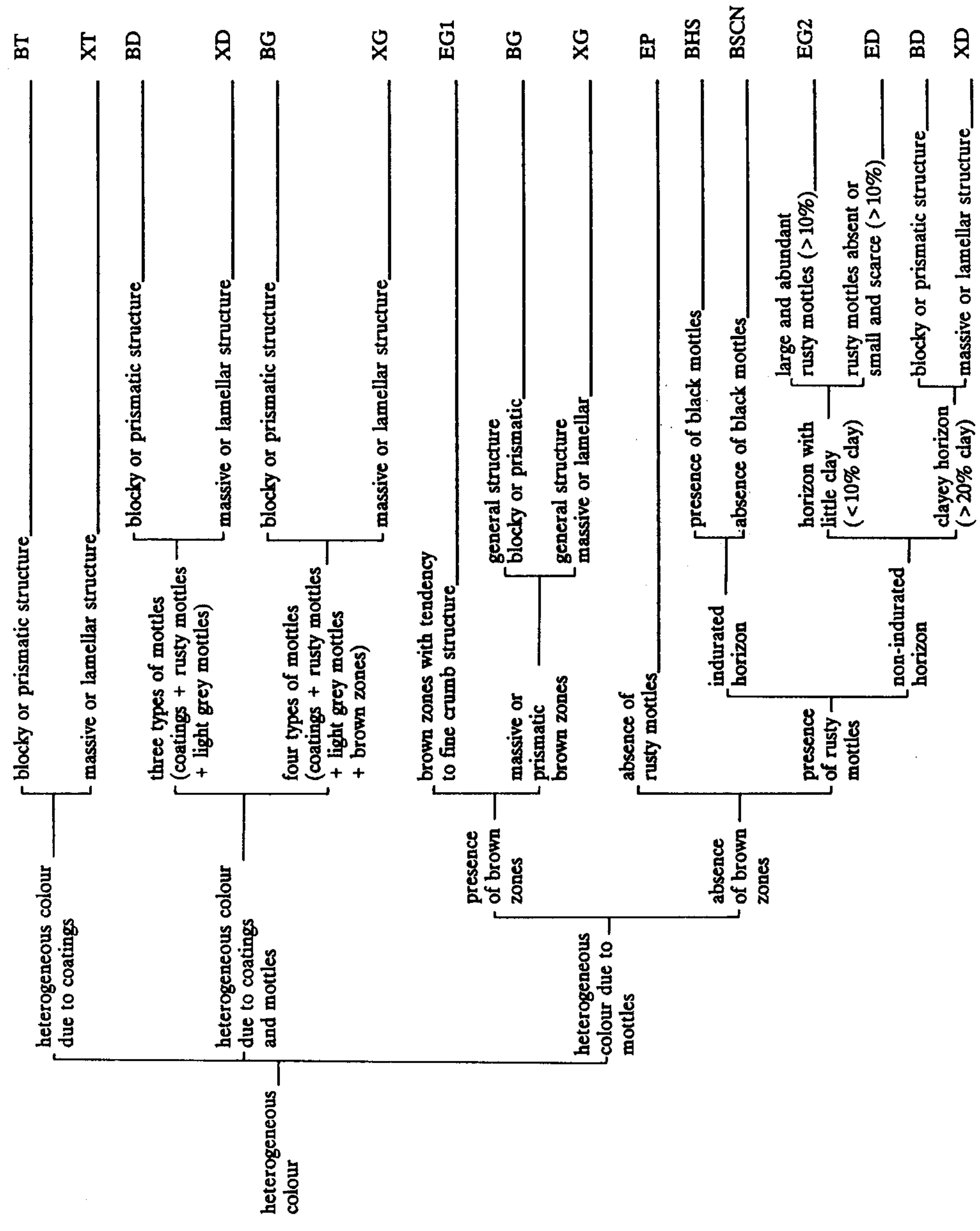

Table 7 (continued)

- homogeneous colour
  - value ≤ 4
    - chroma ≤ 2, hue 10YR — BH1
    - chroma ≥ 3, hue 7.5YR or 5YR — BH2
  - value > 5
    - chroma ≤ 2 — EP
    - chroma 2-6
      - massive or blocky structure, typic colour 6/4 — E
      - fine crumb structure, typic colour 5/6 or 6/6 — ALE
    - chroma > 6
      - fine crumb structure — BS
      - massive or lamellar structure indurated horizon — BSCN

but in multiple profiles it has become the practice to use numerals preceding the horizon designation to indicate soil formation in an earlier phase. As Bos and Sevink (1975) have pointed out, the system works satisfactorily in a monopedomorphic situation but complications occur in complex polypedomorphic soils where a younger soil profile is superimposed on an older one. Ruhe and Daniels (1958) suggested the use of Roman numerals but in recent years Arabic numerals have been preferred. It has also been the practice to omit numbering the horizons of the present soil as it is obviously at the surface, so the first buried profile (or part profile) is given the designation 2 and the next 3. The FAO-Unesco *Soil Map of the World* legend also recommends the use of Arabic numbers which avoids the confusion which arises with the symbols l, I and 1 in typescripts. An alternative procedure, suggested by American and Belgian pedologists, is to use the prime symbol ('), ('') for indicating buried horizons.

Lithological discontinuities also occur within the depth of normal soil formation and often materials of strongly contrasting nature, such as solid rocks overlain with loess or boulder clay or sands and gravels, must be identified to avoid any confusion with the results of soil forming processes. These lithological discontinuities are normally found in the C horizon but are not unknown higher in the profile.

The word layer is used frequently when describing soil horizons in *Soil Taxonomy*. When discussing the surface organic material within the 01 and 02 horizons the litter (L), fermentation (F) and humus (H) subdivisions are described as layers. The C horizon is defined as a mineral horizon or layer and the definition includes contrasting layers of unconsolidated material formerly designated D.

In its *Soil Survey Handbook*, the Soil Survey of England and Wales uses of the term 'layer' for the litter at the soil surface; other organic and mineral components are referred to as soil horizons but lithological discontinuities in the soil and parent material are recognised as layers and indicated by numerical prefixes.

Dutch soil surveyors in their System of Soil Classification for the Netherlands (de Bakker and Schelling, 1966) use the term layer in connection with surface cultivation of raw peat material as in the peaty earthy layer, "a diagnostic surface horizon of peat soils, to distinguish raw peats (still living) from old grasslands or horticultural lands with a moulded surface soil". Other topsoil layers include a mineral earthy layer, brown mineral earthy layer, black mineral earthy layer and an intermediate peaty layer.

The compilers of the legend of the FAO-Unesco *Soil Map of the World*, state that: "Strictly, C and R should not be labelled as "soil horizons" but as "soil layers" since their characteristics are not produced by soil forming factors." In the revised legend (1988) the C horizon is said to be a "mineral horizon (or layer) of unconsolidated material from which the solum is presumed to have formed and which does not show properties diagnostic of any other master horizons". It is admitted that the distinction is not always clear between horizons and layers, since the soil forming processes are often active throughout stratified materials near the earth's surface.

DIAGNOSTIC SOIL HORIZONS

The soil horizon designations described in the previous chapter are intended to express in a short symbolic form the morphology of the soil profile. These designations resulted either from a direct invocation of the soil forming process, or more recently, were decided upon after a consideration of the morphological effects of soil formation. In either case a considerable element of skilled, but subjective, interpretation was used.

In 1951, a new approach to soil classification began to be developed in the USA, and after a number of drafts, the "7th Approximation" was published as a discussion document. After comments had been incorporated from many organisations and individuals around the world, the system of classification was published as *Soil Taxonomy* (Soil Survey Staff, 1975). In this approach to soil classification, named diagnostic soil horizons were selected as a key to the classification system. Six surface diagnostic horizons (epipedons) and 17 subsurface diagnostic horizons were proposed. Although the conceptual basis of what was a diagnostic horizon, or how it was chosen, were not defined, it amounted to a soil horizon or group of horizons which possess a set of quantitatively defined properties. By the use of these criteria and a key, soils may be placed in their correct position in one of the ten orders of the system. The quantitative definition of these diagnostic horizons is such that they cannot be related directly to the master horizons of other systems of horizon designation. In discussions about the development of *Soil Taxonomy* , Smith (1986) explained that the ABC system was not used because of a lack of agreement about its use amongst pedologists. Therefore, he adopted the diagnostic horizon concept which did not carry with it any inherited controversy. However, it has since created its own critics (Webster, 1968; FitzPatrick, 1988b). In many cases the diagnostic horizons of *Soil Taxonomy* are different from the ABC horizons, especially where the latter are too thin and insufficiently developed to meet the criteria - and yet would still be recognisable in the field. The Bt horizon is a good example: where there are insufficient lamellae, or they are too thin to constitute an argillic horizon, it would still be recognisable in the field as a Bt horizon. The diagnostic horizons of Soil Taxonomy are:

Epipedons:	Subsurface horizons:	
Mollic	Argillic	Cambic
Anthropic	Agric	Oxic
Umbric	Natric	Albic
Histic	Sombric	Gypsic
Ochric	Spodic	Calcic
Plaggen	Placic	Petrocalcic
	Salic	Petrogypsic
	Sulfuric	Duripan
		Fragipan

Full definitions of these horizons are given in *Soil Taxonomy* (Soil Survey Staff, 1975) and summaries are provided in the *Field Extract of Soil Taxonomy* (ISM, 1980), the Soil Survey Staff's (1987) *Keys to Soil Taxonomy* and textbooks such as *Soil Genesis and Classification* (Buol, Hole and McCracken, 1973).

Since the development of *Soil Taxonomy* , the concept of diagnostic horizons has been used to make several other classifications more quantitative (for example, those of Brazil, South Africa and the Legend for the FAO-Unesco *Soil Map of the World* .

The FAO-Unesco (1974) *Soil Map of the World* legend includes a system of diagnostic horizons which are derived from those of *Soil Taxonomy* . A system of horizon designations is employed in association with 13 diagnostic horizons. The horizon designations have been given elsewhere and the diagnostic horizons are as follows:

Histic H horizon	Argillic B horizon	Calcic horizon
Mollic A horizon	Natric B horizon	Gypsic horizon
Umbric A horizon	Cambic B horizon	Sulfuric horizon
Ochric A horizon	Spodic B horizon	Albic E horizon
	Oxic B horizon	

A number of diagnostic properties, which are not considered as horizons, are also used in the definitions of the diagnostic horizons. These refer to the properties of andic soil material, ferralitic, ferric, fluvic, hydromorphic, nitic, vertic properties respectively.

In the Brazilian system (EMBRAPA, 1981; 1988), 20 diagnostic horizons are employed to categorise soils. Many of these correspond directly or are closely related to the diagnostic horizons of the *Soil Taxonomy* system.

The Brazilian diagnostic horizons are:

Surface horizons	Equivalents
Horizonte turfoso	histic epipedon and FAO-Unesco H horizon
Horizonte A humico	umbric epipedon and FAO-Unesco Umbric A
Horizonte A chernozemico	mollic epipedon
Horizonte A proeminente	umbric epipedon
Horizonte A moderato	ochric epipedon
Horizonte A fraco	ochric epipedon
Horizonte A antropico	anthropic epipedon
Subsurface horizons	
Horizonte B textural	adapted from argillic B horizon
Horizonte B latossolic	hydromorphic oxic horizon
Horizonte B incipiente	cambic horizon
Horizonte B natrico	natric horizon
Horizonte B espodico	spodic horizon

Horizonte B plintico	plinthite and petroplinthite
Horizonte glei	G horizon of Manual Supplement (1962) and partly hydromorphic properties of FAO-Unesco
Horizonte albico	albic horizon
Fragipan	fragipan as in Soil Taxonomy
Duripan	duripan as in Soil Taxonomy
Horizonte calcico	calcic horizon
Horizonte sulfurico	sulphuric horizon
Horizonte salico	salic horizon

A discussion of the Brazilian system of soil classification and its use of diagnostic horizons is given by Camargo *et al.* (1986).

In the Republic of South Africa, soil classification is built upon a number of diagnostic horizons which have been chosen to suit South African conditions. These include five surface horizons and 15 subsurface horizons as follows:

Surface horizons	Subsurface horizons
Organic O horizon	E horizon
Humic A horizon	G horizon
Melanic A horizon	Red apedal B horizon
Vertic A horizon	Yellow-brown B horizon
Orthic A horizon	Red structured B horizon
	Soft plinthic B horizon
	Hard plinthic B horizon
	Gleycutanic B horizon
	Prismaticutanic B horizon
	Pedocutanic B horizon
	Lithocutanic B horizon
	Neocutanic B horizon
	Ferrihumic B horizon
	Regic sand
	Stratified alluvium

Full details of these horizons are contained in *Soil Classification: a Binomial System for South Africa* (MacVicar *et al.*, 1977). In this case, the diagnostic horizons are defined in association with the horizons of the ABC system which succeeds in bringing the two systems closer together.

A similar approach took place in the Netherlands where the special nature of the parent materials necessitated a different approach from that adopted in many other countries (de Bakker and Schelling, 1966).

Peaty earthy layer	Clayey peaty earthy layer
	Clay-poor peaty earthy layer

Mineral earthy layer	Brown mineral earthy layer
	Black mineral earthy layer
Thick A_1 horizon	
Moderately thick A_1 horizon	
Thin A_1 horizon	
Prominent peaty B horizon	
Prominent Podzol B horizon	Prominent humus podzol B horizon
	Prominent moderpodzol B horizon
Banded B horizon	
Brick layer	
Reworked soils	

These defined diagnostic horizons are utilised in the classification system to allocate soils to their correct position in the taxonomy. However, these definitions are based firmly on the morphological ABC system and so there is no dichotomy between horizon designation and the classification system.

Developments since Soil Taxonomy

In the period since the publication of *Soil Taxonomy* , assimilation of the ideas contained in it has occurred and aspects have been absorbed into the national systems of soil classification in many countries. As a result of experience gained during the last decade, several international committees have been looking into improvements which might be made to the original proposals of *Soil Taxonomy* and these reports are becoming available. e.g. the final report of ICOMOX, the International Committee on Oxisols, (Buol and Eswaran, 1988). No new epipedons have been suggested, but one new subsurface diagnostic horizon has been introduced, the kandic horizon (Soil Survey Staff, 1987, Fanning & Fanning, 1988).

The progress of soil science has necessitated improved definition of soil characteristics, including soil horizons, and this has led to several projects and developments which are relevant to the subject of soil horizon designation. Some of these are mentioned in the following paragraphs.

The *Projet de classification des sols* was prepared by a working group of ORSTOM (Segalen and van Diepen, 1984). It has explored the idea of using named diagnostic horizons in the approach to the classification of French soils. In this system no reference was made to the ABC system, as it was considered to be too narrow to characterise and identify all horizons, even when supplementary indices and letters are added. Additionally, the numbers and letters had acquired genetic significance which pre-supposes the processes of soil formation producing the horizon are known, which is not the case. For the purposes of this project the profile (pedon) is subdivided into four parts: organic, humus, differentiated mineral material and patent material, not all of which way be present simultaneously in any one soil.

Organic the organic part of the soil in which accumulation of organic matter occurs in distinctive layers distinguishable from incorporated humic material. The structure of the organic material may or may not be recognisable, but the organic matter is the major constituent and the organic carbon content is high. It is proposed that such horizons are called organons. Fibric, folic, hemic and sapric are suggested with qualifying adjectives pachic, leptic, eutric and dystric. The main definitions are taken from *Soil Taxonomy* .

Humus the humus part of the soil relates to the horizon where organic matter is lower in amount and is broken down and integrated into the upper part of the mineral soil profile, giving it a darker color. It is proposed to call these horizons humons. Two major humons are proposed: sombrom and pallidon defined by organic matter content and colour according to the Munsell Soil Colour Charts. Surface horizons which do not contain sufficient amounts of organic matter to meet these requirements are either epimineralons or epithalterons.

Differentiated mineral material the parts of the soil profile composed dominantly of pedologically altered mineral material with a lower organic carbon content, brighter colours and differentiated by structure from the material beneath, are proposed as mineralons. Several mineralons may exist in one profile, but in some profiles only organons may be present. The humons and the mineralons together constitute the solum. Mineralons are distinguished by their constituents and their organisation and include: halons, thions, sulfons, gypsons, carboxitons, andons, bisiallitons, ferbisiallitons, monosiallitons, fermonosiallitons, oxidons and cheluvions.

Parent material the loose material of the lower parts of the pedon, derived from underlying rocks by weathering, constitutes the parent material. It may be distinguished from the humons by lower organic matter content and from the mineralons by a lack of structural modification. Two categories are distinguished: alterite, resulting from the chemical breakdown of the parent rock without displacement so that the structure and nature of the parent rock is still recognisable; and pedolite, which is a mixture of soil and rock constituents which have been transported by natural agencies from their original sites, eg. alluvium and loess.

These developments appear to have been overtaken by the publication of the Référentiel Pédologique Français, proposals 1 and 2, (AFES, 1987, 1988) in which a list of horizons de référence is given which constitutes the basis of the system. Horizon designations may be constructed from capital letters for the horizons de référence and a list of 16 lower case letters, which denote special features, only some of which are comparable with the lower case designations of the FAO-Unesco system. The horizons de référence include:

- O horizons organiques, distinguished by the degree of breakdown of plant material.
- H horizons histiques, with saturated peaty forms using the concept of fibric, mesic and sapric forms.
- A horizons with carbonate, chernozemic, anmoor, allophanique, vitrique, aluminique and atipique (young) characteristics.
- E horizons éluvials.
- B horizons include a B texturel (BT), B podzolique (BP) and B fersiallitique (BF).

Additionally horizons ferrique (FE), calcarique (K), structural (S), vertique (V), materiaux thionique (TH) and gypsique (Y) are distinguished. Horizons where reduction, permanent (Go) or temporary (Gr) occurs and different types of parent material, matériaux limniques et terreux (M), roche cohérente dure (R), and materials without pedological structure (C) are indicated.

The lower case letter suffixes proposed are:

cn concrétionné ou nodulaire
cr cryoturbé
d dégradé = à dégradation morphologique
fe riche en fer
g horizons redoxiques (rappel)
h particulièrement riche en matières organiques
k à début d'accumulation de calcaire
l horizons labourés
m induré
na natrique
p de profondeur ou pélosolique
s riche en sesquioxides
v à caractères vertiques
w gelé
x à caractères fragiques
y à caractère gypseux

The Canadian System of Soil Classification (Canada Soil Survey Committee, 1978) also combined the system of horizon designation with a number of diagnostic horizons defined to suit Canadian conditions. Horizon designations, based on the ABC system, are defined in considerable detail, and therefore begin to approach the diagnostic horizon in concept. However, a number of named diagnostic horizons and layers of mineral and organic soils are employed:

Chernozemic A	Podzolic B horizon	Limno layer
Duric horizon	Solonetzic B horizon	Cumulo layer
Fragipan	Mull	Terric layer
Ortstein	Lithic layer	Hydric layer
Placic horizon		

At approximately the same time as the scheme of soil classification in *Soil Taxonomy* was being developed in the USA, FitzPatrick (1967, 1971, 1980, 1988a) was devising a scheme of soil classification which develops further the idea of a defined horizon. With much justification, FitzPatrick (1967) argues theoretically that "although homology exists in many soils, it is by no means universal". It is therefore difficult to construct a classification with a fixed number of classes. In practice, it means that the juxtaposition of soil horizons produces a very diverse set of relationships which is difficult to classify systematically. Additionally there is the problem that some of the morphological features of soil horizons can be related to current soil forming processes, but other features may relate to processes no longer operating.

A number of soil horizon sequences are depicted in the hypothetical profiles in Figure 10 which illustrates the difficulty. Profiles A and B are identical; they have the same horizons which occur in the same order in the profile. Profile C is partly homologous with A and B as they possess horizons 1 and 3 in common, but horizon 3 is missing. The profile D is partly homologous with profile E, but it has an additional horizon 4 below horizon 3. Finally, profile E is similar to A and B but it has the additional horizon 4.

This problem is well known to soil surveyors and it is not an unusual situation to meet in the field. Although there are many soils which are homologous, sufficient to enable the present systems of classification to be reasonably effective, there are many combinations of horizons which make the task difficult.

A second problem is that soil horizons intergrade with each other horizontally with few abrupt changes. Gradational features are particularly difficult to accommodate in a classification with rigidly fixed classification categories. Webster *et al.* (1976) states from a statistical viewpoint that 'soil populations generally are distributed evenly with few gaps and little clustering'. This lack of natural breaks in the range of soils makes the task of the soil taxonomist far from simple.

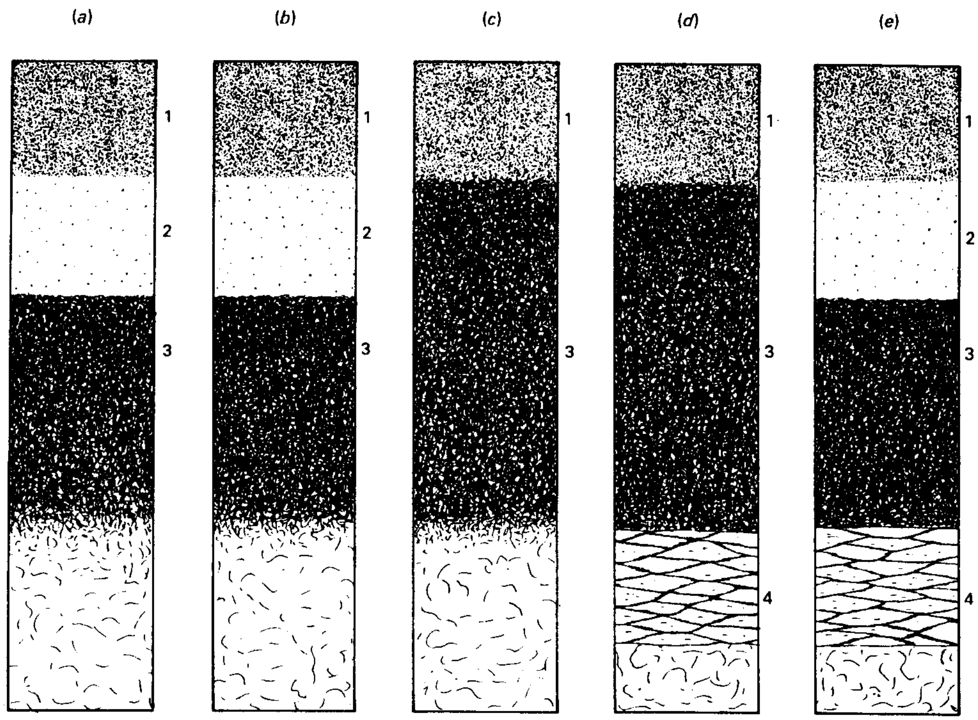

Fig. 10 Five profiles showing four different sequences of horizons (FitzPatrick, 1980).

Thus, arbitrary boundaries have to be created which do not delimit discrete entities. So, FitzPatrick (1980) claims it is best to accept that it is impossible to create an ideal classification system using the complete soil profile. Consequently, he recommends distinguishing a soil by its horizons, then arranging these on an *ad hoc* basis into meaningful groups at higher levels of classification. Altogether he has proposed 76 distinctive horizons as 'reference segments' based upon colour, clay content, cation-exchange capacity and weatherable minerals. With this number of reference segments FitzPatrick asserts that it is possible to indicate with reliable accuracy transitional situations as well as the central concept of his reference horizons. A list of the horizons and their position in the soil profile is given in Table 8.

Table 8 Horizon grouping according to position (FitzPatrick, 1967)

UPPER	MIDDLE	LOWER
ALKALON	ALKALON	ALKALON
—	ALTON	—
AMORPHON	AMORPHON	AMORPHON
—	ANDON	—
ANMOORON	—	—
—	ARENON	Arenon
—	ARGILLON†	Argillon†
BURON	—	—
—	Calcon	CALCON
CANDON	Candon	—
—	Celon	CELON
—	Cerulon	CERULON
CHERNON	Chernon	—
CHLORON	CHLORON	CHLORON
	CLAMON†	
CRUMON	—	—
—	Cryon	CRYON
Cumulon	CUMULON	—
DERMON	—	—
—	Duron	DURON
FERMENTON	—	—
—	FERRON†	Ferron†
FIBRON	FIBRON	FIBRON
—	Flambon	FLAMBON
—	FLAVON	Flavon
—	—	FRAGON
GELON	Gelon	—
—	GLEYSON	GLEYSON
—	GLOSSON	GLOSSON
—	GLUTON	—
—	Gypson	GYPSON
GYTTJON	GYTTJON	GYTTJON
Halon	HALON	HALON
HAMADON	—	—
—	HUDEPON	—
HUMIFON	—	—
	HUSESQUON†	—
HYDROMORON	—	—
—	—	ISON

UPPER	MIDDLE	LOWER
—	JARON	—
KASTANON	—	—
—	KRASNON	Krasnon
KURON	—	—
—	LIMON	—
—	LITHON	—
LITTER	—	—
LUTON	—	—
LUVON*	Luvon*	—
—	MARBLON	MARBLON
MINON*	Minon*	—
MODON*	—	—
MULLON	—	—
—	ORON†	—
—	Pallon	PALLON
—	PELON	PELON
—	Pesson	PESSON
—	PLACON†	PLACON†
PLAGGON	Plaggon	—
—	PLANON†	—
PRIMON	—	—
—	PROXON	—
PSEUDOFIBRON	PSEUDOFIBRON	PSEUDOFIBRON
—	ROSSON†	ROSSON†
—	RUBON†	RUBON†
—	RUFON	—
—	Sapron	SAPRON
SERON	—	—
—	SESQUON†	—
—	SIDERON	SIDERON
—	SOLON†	—
SULPHON	SULPHON	SULPHON
TANNON	—	—
—	Thion	THION
VERTON	VERTON	—
Veson	Veson	VESON
—	ZHELTON	Zhelton
ZOLON*	Zolon*	Zolon*

*Contain less sesquioxides or clay than the horizon below.
†Contain more sesquioxides or clay than the horizon above or below.
Lower case indicates lower frequency.

In the Netherlands, de Bakker (1987) has proposed a revised notation in place of the one formerly in use (de Bakker and Schelling, 1966). The master horizon designations O, A, E, and B are retained and the letters C and R are used for parent materials where soil forming processes have had a minor, or no influence on the soil. Specific features of these master horizons are indicated by lower case letters placed after the master horizon symbol. These are:

a anthropic
b buried
c concretions
e eluvial
g gley
h humus
i initial (unripe)
p ploughed
r reduced
s sesquioxidic
t textural
u unspecified
w weathered

In 1988, a revision of the legend of the *Soil Map of the World* took place and includes recommendations to introduce a Fimic A horizon in which the anthropic and plaggen epipedons of the *Soil Taxonomy* are combined. Problems in separating the oxic and argillic horizons in the field in tropical regions has led to the re-definition of these horizons as the Ferralic and Argic B horizons respectively. Petrocalcic and petrogypsic horizons have been introduced at the diagnostic horizon level and some new diagnostic properties including fluvic properties, continuous hard rock, nitic, sodic and geric properties aim to improve the definition of Fluvisols, Leptosols, Nitisols, Solonchaks and Ferralsols respectively (FAO-Unesco, 1988).

This brief review of diagnostic horizons and other systems of horizon identification has been included in an attempt to keep in mind the various methods of assessment of soil horizons. There has been a regrettable schism within pedology which has made the relationship of diagnostic horizons with soil horizon designations difficult. As is seen in the later section of this discussion document, the gap between the two approaches has been largely bridged by the adoption of morphological criteria, rather than genetic supposition, in recent systems of horizon designation. It now needs a very small change in position by the various proponents of different approaches to soil horizon nomenclature for a large measure of agreement to follow.

The advantages of this situation was fully appreciated by the participants at the Conference on Soil Horizons held in Rennes, France in September 1989, where it was acknowledged that the traditional methods of horizon designations would continue to be used. However, for detailed studies and an understanding of the vertical and lateral relationships of soil horizons, the use of the systems of FitzPatrick and Aurousseau had many advantages.

USE OF SOIL HORIZON DESIGNATIONS

Information received from national soil survey institutes

Requests for information were sent to 47 National Soil Survey Institutes, 12 in Africa, 11 in Asia, 15 in Europe, 2 in Australia and 7 in North and South America. At the time of compilation the following replies have been received. Copies of the systems mentioned in this report are held in the ISRIC library.

Australia Australian pedologists use the ABC system of soil horizon designation in conjunction with numerical subscripts plus a limited number of letter subscripts without genetic implications. The system is clearly presented in 'Australian Soil and Land Survey; Field Handbook' (McDonald *et al.*, 1984).

The L, F and H nomenclature has not been adopted and organic horizons are indicated by O well drained, and P accumulated in conditions of excessive wetness. Many Australian soils do not have less clay or lower amounts of sesquioxides in the eluvial horizon (A_2) and so pedologists are reluctant to adopt the E notation of certain European systems and the FAO *Guidelines for Soil Profile Description*. The definition of the B_2 in the Australian system includes the phrase 'maximum development of pedological organisation' which has led to some differences of opinion, although most people felt they knew what the phrase was intended to define. The symbol G was not needed as the subscript g covered all cases satisfactorily. The use of the subscript s was sometimes difficult as an intense colour is not always related to increased iron content.

The vertisols were acknowledged as a difficult group of soils with which to use the horizon designations; there is a feeling that the A horizon could be extended to all dark coloured horizons and that they should not be defined solely on structure. The yellowish-brown clays in gilgai formation should be thought of as the B horizon.

Austria Information supplied by the Bundesanstalt für Bodenwirtschaft in Vienna indicates that the system of horizon designation used by Austrian pedologists dates from publications by Fink (1969) and Krabichler (1984). Organic horizons are referred to as O with l, f and h subscripts. A, E and B horizons are used with normal letter subscripts, but poorly-drained situations are indicated by G_o for the oxidised zone and G_r for the reduced zone following the custom in German horizon designation schemes.

Canada Following the publication of *The Canadian System of Soil Classification* (CSSC, 1978), the soil science community in Canada has used the system of horizon nomenclature described in it. This retains the ABC mineral horizons with layers R for consolidated bedrock and W for materials situated with water. Minor revisions have taken place to the 1978 system, and will shortly be published.

France The system of horizon nomenclature and definitions used in France is currently under review; the following comments are made on the information available. Since 1979 discussions have been taking place about a new approach to soil classification (Segalen and van Diepen, 1984) by adopting a diagnostic horizon approach. The system of soil horizon designations currently in use is contained in the *Manuel pour la description des sols sur le terrain* (Maignien, 1980). This system employs the master horizons H, O, A, B, C and R which indicate the principal character of a horizon. To these may be added lower case letters to indicate the nature of the horizon and numbers to show vertical subdivisions. The subscript letters follow the FAO *Guidelines for Soil Profile Description* in most cases.

Information provided by a working group of the Institut National Agronomique Paris-Grignon, Département des Sols stated that re-definition of a number of soil horizons is in progress. As a result of this work proposals have been drawn up, some of which are in line with the FAO *Guidelines* and others which are new. An anthropic horizon (Z), ploughed horizon (L) are proposed with G for mottled horizons and GO for reduced gley horizons. Capital letter symbols are suggested also, for structural B horizons (S), podzolic B horizons (BP), textural B horizons (BT), calcareous B horizons (BK) and B horizons rich in iron and aluminium oxides (BO).

The Association Française pour l'Etude du Sol (1987, 1988) has further considered the designation of horizons and detailed definitions of horizons are given (see Strategy 5). These confirm the close correspondence of master horizons H, O, A, E, B, C with other systems, and symbols K, Y, S, J are introduced for calcareous, gypseous, structural and juvenile characters respectively. Some designations in the previous proposals appear to have been discarded.

Greece The Director of the Soil Science Institute in Athens has replied stating that the horizon designations used in Greece are those of the FAO *Guidelines for Soil Description*.

Hungary Information provided indicates that a genetic system based on A, B, C, D, G master horizons is used in Hungary (Szabolcs, 1966). However certain subscripts are recorded to indicate variations within the master horizons. A revised version has been published by Horvath *et al.* (1987).

Ireland The National Soil Survey of Ireland based at the Agricultural Institute, Johnstown Castle, Wexford, uses the soil horizon designations described in the Soil *Survey Manual Supplement* and reprinted in *Soil Taxonomy*.

Israel The system of horizon designation in the FAO *Guidelines* is used in Israel. Soil scientists in Israel are concerned about the horizon designation of Vertisols; opinion favours designation of the upper plough layer or self-mulching layer as A with the dominant cracking allocated to B1, the zone of dominant slickensises B2 and where a calcic horizon occurs B3ca. Pedogenetic calcic horizons should not be labelled C but Bca in the Arid Brown soils recognised in the Israeli classification.

Aeolian dust is an important contribution to soil profiles in Israel and leads to buried horizons.

Japan Soil horizon designations used in Japan are based upon the FAO *Guidelines* (1977) with a number of modifications to suit Japanese conditions (Matsui, 1982). Widespread cultivation of paddy rice in Japan has necessitated specific proposals for soil horizon designations for paddy soils (Otowa, 1967).

Kenya The Kenya Soil Survey has used the FAO *Guidelines for Soil Description* since its inception in 1972 and after 1977 has used the revised version *Guidelines for Soil Profile Description*. The Kenya Soil Survey has a coordinating function for soil surveys in the country and advises other agencies to apply the FAO *Guidelines* in its investigations.

Netherlands The Netherlands Soil Survey Institute has based its horizon designation on those presented by de Bakker and Schelling (1966). Revision of the scheme has recently been undertaken (de Bakker, 1987).

Pakistan Until the present day, the Soil Survey of Pakistan has been using the FAO *Guidelines for Soil Description* for its soil horizon designations. In future they will be using the USDA revised nomenclature for designation of master horizons contained in the 1981 revision of the *Soil Survey Manual*.

Peru The Director of Soils in the Oficina Nacional de Evaluacion de Recursos Naturales (ONERN) states that the horizon designations in use in Peru are those defined in the 1981 *Soil Survey Manual*. However for some features, the FAO *Guidelines* is used.

Philippines Until recently the Philippine Bureau of Soils has been using the horizon designations in the 1951 *Soil Survey Manual* but currently the revised versions of soil horizon designations contained in the 1981 *Soil Survey Manual* are being implemented.

Republic of South Africa The Soil and Irrigation Research Institute of the Department of Agriculture and Water Supply replied for the pedologists in South Africa stating that they use the master horizons O, A, B, C, R, E and G with numerical subdivisions within horizons. The diagnostic horizons which form the key to the classification system are defined in terms of these master horizons; there is therefore no great divergence between soil horizon designation and classification.

Rumania Soil surveys in Rumania use a combined pedogenetic-diagnostic system of soil horizon designation (Research Institute for Soil Science and Agrochemistry, 1979). Its basis is the A, E, B, C master horizons with subscripts, but these are closely defined as in the Canadian, England and Wales and New Zealand systems.

Sudan The Soil Survey Administration in Sudan, based at Wad Medani advises that it uses the soil horizon designations contained in the FAO *Guidelines.*

Thailand The soil horizon designations used by Thai soil scientists in their soil profile descriptions are those of the USDA 1981 *Soil Survey Manual* , reproduced in the *National Soils Handbook* .

United Kingdom The horizon designations used in Great Britain have been based upon those contained in *Soil Classification in England and Wales* (Avery, 1980). They are stated to be in general accord with international usage and utilise the master horizons A, E, B, C, R with strictly defined subscripts for additional features. The UK is one of the few countries in the world to use the symbol O rather than H for saturated organic matter accumulations. A draft of an agreed joint Soil Survey of England and Wales and Soil Survey of Scotland Field Handbook is currently under consideration.

The United States The predecessor of many systems of soil horizon designation can be traced back to the American adoption of the ABC system in the 1930s. It led directly to the development of the scheme published in the 1951 *Soil Survey Manual* . This was extensively revised in the *Manual Supplement* of 1962, which was reproduced in Chapter 3. Another revision took place in the 1981 *Soil Survey Manual* reported by Guthrie and Witty (1982), which has in turn been used to produce the *Designation for Master Horizons and Layers in Soils* (Department of Agronomy, Cornell University, 1986), also reproduced in *Keys to Soil Taxonomy* (Soil Survey Staff, 1987).

In all these revisions the consistent features have been the master horizons O, A, E, B, C and R. The number of subordinate distinctions with the master horizons has grown in number until almost all letters of the alphabet have been used to indicate some part of horizon morphology. Many of the symbols used are identical to those in the FAO *Guidelines* however some are not common to both systems.

The Union of Soviet Socialist Republics The early development of the ABC system of soil horizon designations and the alternative proposals have been presented in Chapter 3. The basic outline of soil horizon designation in the Soviet Union is given in text books by Kovda (1973) and Glazovskaya (1983), and an account of the basic system used since the 1950s is given in *Pochvennia Syemka* (Tiurin *et al.* , 1959). Examples of the use of the ABC system currently employed are given by Egorov *et al.* (1987).

Zambia The Soil Survey of Zambia tabulates the horizon designations in use for its soil surveys in its *Manual for Soil Profile Description* . This system broadly follows the example of the 1981 revision of the *Soil Survey Manual* .

Zimbabwe The Chemistry and Soil Research Institute reports that it is not called upon to use soil horizon designations in much of its routine work, as the Zimbabwe

Soil Classification does not require the use of diagnostic horizons. However, for correlation purposes, use has been made of the FAO *Guidelines*.

Depiction of soil horizons

For the professional soil scientist the horizon designations themselves are sufficient to generate a mental picture of the profile morphology and the processes which have shaped it. However, to aid the process for other people who require a rapid introduction to the soil horizons present or to students who wish to encapsulate the essential facts in diagrammatic form, the visual depiction of soil horizons is a valuable aid. Duchaufour (1960) in *Précis de Pédologie* (translated by T.R. Paton in 1982 as *Pedology*) employs the following symbols (Fig. 11).

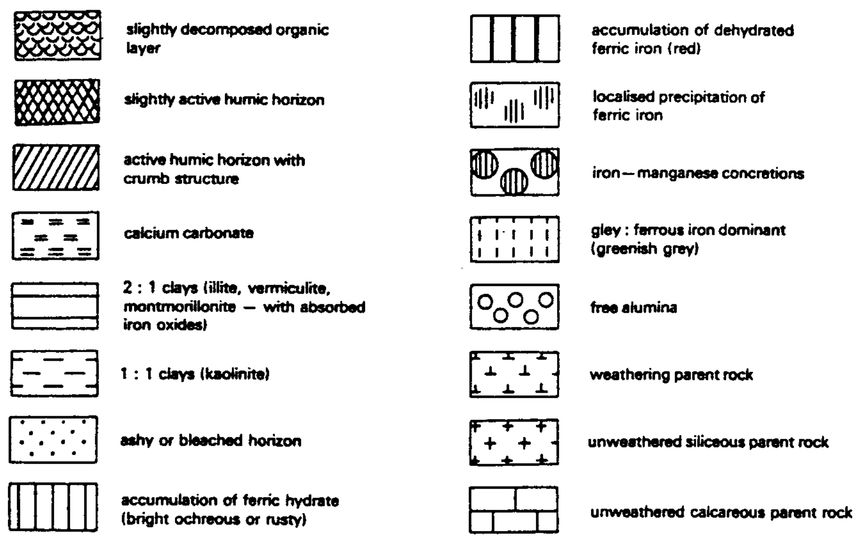

Fig. 11 Depiction of horizons in symbols

These symbols may then be used singularly or in combination to indicate the dominant morphological character of the horizon within a profile. A selection of podzolised soil profiles, together with (Duchaufour's) soil horizon designations, is given in Figure 12.

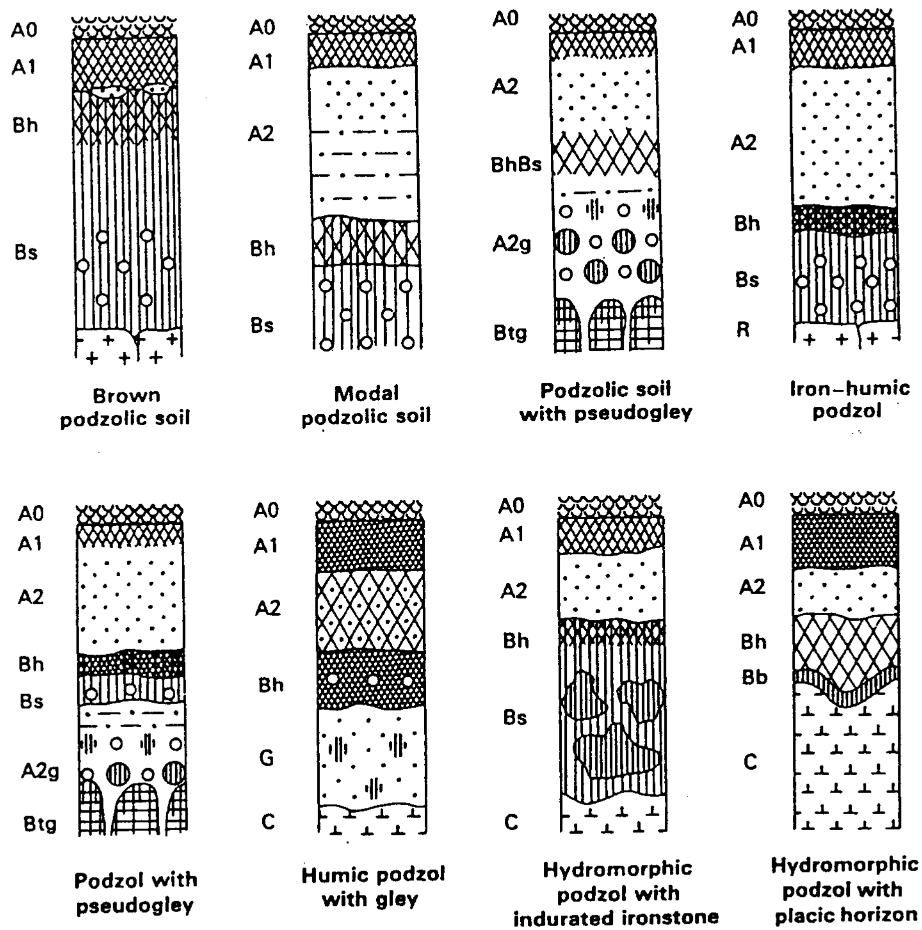

Fig. 12 Podzolized soil profiles (Duchaufour, 1960)

Where it is required to illustrate the relationship of the processes operating in the genesis of soil horizons, it is possible to use a diagrammatic profile with horizon designations and directional arrows suggesting the movement of soil constituents (Fig. 13).

Profile diagrams are also extremely useful to demonstrate the differences between and within soil classification groupings. An example from the *Canadian System of Soil Classification* (Canada Soil Survey Committee, 1978) of the different subgroups of Brunisols also indicates the range commonly occurring in the depth at which horizons lie below the surface (Fig. 14).

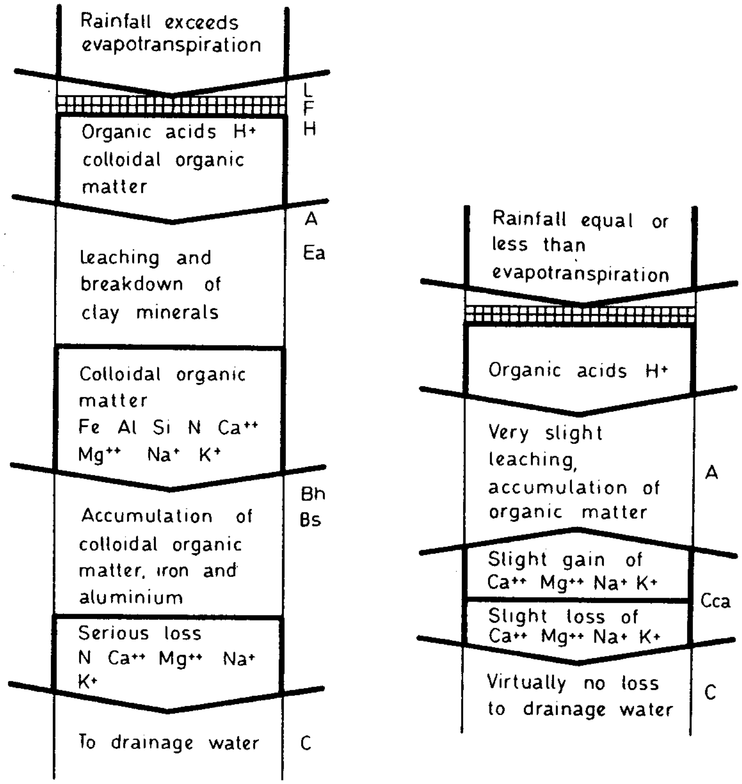

Fig. 13 Movement of soil constituents in podzolization and calcification (Bridges, 1980)

Compatibility with data-handling systems

Within the past decade great advances have been made in machine handling of data of all kinds, including those arising from soil surveys. Consequently many soil survey organisations and individual soil scientists have developed systems to help manipulate the large amount of information produced (Baumgardner and Oldeman, 1986).

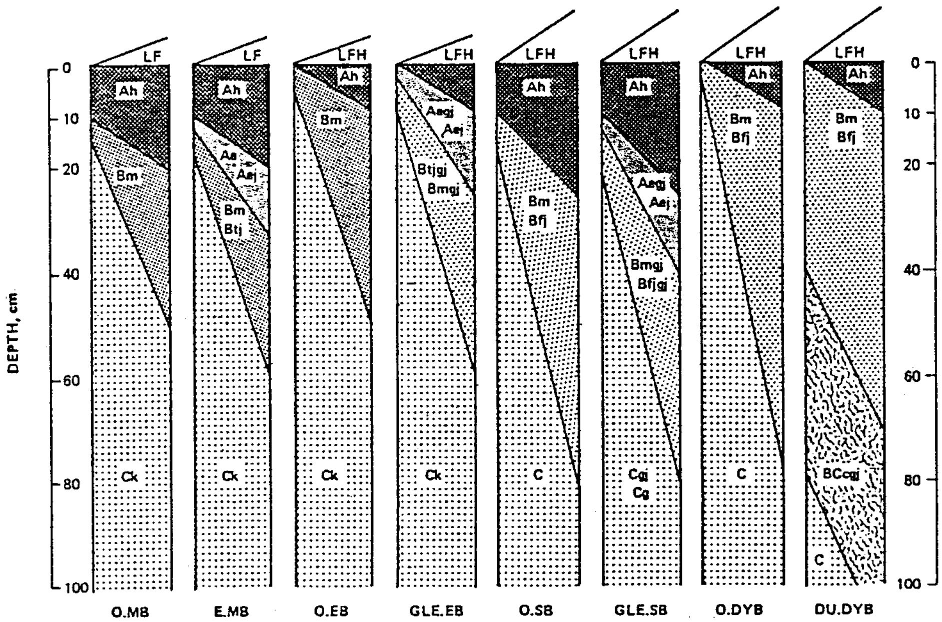

Fig. 14 Diagrammatic horizon pattern of some subgroups of the Brunisolic order (CSSC, 1978)

Although it is possible to convert data already gathered into a form acceptable for machine handling, it is a laborious task and it is helpful if the data are gathered by the surveyor when he makes his soil description in a form compatible with a data-handling system. Several systems exist and an example has been described by Hazelden *et al.* (1976) which satisfactorily handles the factual information about the soil profile. It is then possible to convert this information by computer into a user-friendly format which can be easily read (Webster *et al.*, 1976). Soil horizon designations are recorded on the field soil description card of the Soil Survey of England and Wales but they do not figure in the handling system. In the *Field Handbook* (Hodgson, 1976) it is stated that they can be coded subsequently after the laboratory data become available.

Fortunately, it is no longer necessary for the initial forms neither to be restricted by number of columns nor to be so all-inclusive that the form runs to several pages in length. Where possible, numeric coding should be avoided and use made of acceptable, familiar abbreviations. In this way errors may be avoided and the information can easily be checked (Ragg, 1986).

In all soil profiles there are many features to record and the value of recording objective, measurable features has been stressed, rather than the possible mode of genesis implied by soil horizon designations. However, as stated elsewhere, the soil horizon designations properly used can add greatly to the value of descriptions. Thus, the soil horizon designation is in direct competition with other data for a place in the system. In the system suggested by FAO (1986) seven characters are allowed for horizon designation; the first for lithological discontinuities, three for master horizon designation, two for the horizon modifier and the last one for any subdivision of the master horizon. There is no technical reason why the designations should not be used directly, but even where space in the data- handling system is limited it is still possible to code them by the use of a dictionary entry (as in Strategy nº3), thus reducing the number of characters required for insertion into the system. However this is achieved, it would be desirable for symbols to be uniform i.e. formed of one master horizon symbol and one subscript or one master horizon symbol and two subscripts throughout. At present some systems have two letters for some symbols (fe for iron pans or cs for sulphates) and one for others (t for clay or g for gley).

PROPOSALS FOR DISCUSSION

In this monograph, information has been assembled about the origins and development of soil horizon designations. The gradual sophistication and use of soil horizon designations has been reviewed in an attempt to identify current working practices and to search for any trends which may point the way towards acceptable improvements of the present systems. Today's use of soil horizon designations has been reached as the original *labels* were first replaced by *genetic* systems which in turn have been replaced by *morphological* systems in which the importance and significance of observable and measurable characters in the soil is stressed. Formerly, when genetic supposition played a greater part in horizon designation, the use of these symbols was less satisfactory and detracted from their value. So, it is necessary to differentiate clearly between the factual criteria required for description and classification and the interpretative nature of the horizon designation. However, as the factual information on which the designations are based, and the diagnostic criteria used in classification now are essentially the same, the former clash between subjective genetic designations and objective classification no longer is a point of dispute.

The following five strategies were put forward in a working document issued by ISRIC in December, 1987. They were intended to stimulate discussion and to elicit responses from as many individuals and organisations as possible. Many comments were received and those persons kind enough to provide helpful and stimulating advice are listed in the acknowledgements. The strategies range from a slight modification of existing systems to an exploration of some alternative approaches. As there are already several systems available, it was not thought advisable to produce yet another scheme which might further confuse the situation. At the colloquium organised in Rennes in 1989 the subject of soil horizons and their nomenclature was discussed. The various systems were described by their proponents but the meeting did not result in any definite conclusions which could be carried forward to the International Society as a recommendation for future use. Despite the strenuous efforts of some contributors to promote change, the colloquium showed how deeply engrained is the use of the contemporary nomenclature, whether ABC or the use of diagnostic horizons, as no discussions took place without their use.

It is clear that pedologists find the need for a system of soil horizon designations of some sort. The following five strategies are presented in and attempt to resolve the present problems.

Strategy No. 1 (Rationalisation)

This proposal amounts to a simple rationalisation between the existing FAO-Unesco (1977) and USDA-SMSS (Department of Agronomy, 1986) systems for horizon designation. A major advantage of using either of these schemes as a basis for rationalisation is that their use is already well established, the master horizons and

15 of the letter subscripts already have the same meaning in both systems (see pages x and y).

In order to rationalise the two systems, it is recommended that the letters a, d, e, i, j, o, r, u, and v are used in the following way:

- a slightly decomposed organic matter
- d organic matter of intermediate decomposition
- e highly decomposed organic matter
- i occurrence of permafrost
- j occurrence of jarosite
- o occurrence of residual sesquioxides
- r strong reduction as a result of ground water influence
- u unspecified; this suffix is used in connection with A and B horizons which are not qualified by another suffix but have to be subdivided vertically by figure suffixes (for example, A_{u1}, A_{u2}; B_{u1}, B_{u2}). The addition of u to the capital letter avoids confusion with the former genetic notation A_1, A_2 etc. If no subdivision of the horizon occurs, then the symbols A or B can be used without it
- v occurrence of plinthite

If agreement could be reached along these lines with these symbols, the problems of using soil horizon designations would be minimised with the least amount of difficulty.

Strategy No. 2 (All subscript letters available for each horizon)

This strategy is a proposal to give the existing systems of soil horizon designation greater scope and flexibility. The existing master horizons are used and where possible the letter subscripts conform to common practice. It differs from Strategy No. 1 in that the present use of lower case suffix letters includes almost all the 26 letters of the Latin alphabet, most of which are used to symbolise the character of the B horizon, leaving few symbols for the designation of other horizons. It is possible to allow each master horizon to utilise as many of the lower case letters of the alphabet as is required. Some symbols should remain the same for all horizons, for example, gleying (g), accumulation of carbonate (k), accumulation of salts (z) or buried (b), as these features are indicative or common to horizons in different parts of the profile. However, such multiple use of subscript letter symbols could be confusing.

Suggested letter suffixes which qualify the master horizon symbols are as follows, others may be deemed necessary in particular environments:

H horizon	a	well-decomposed organic material (sapric)
	b	buried or bisequal soil horizon
	c	coprogeneous earth
	d	diatomaceous earth
	e	partly decomposed organic material (hemic)
	f	undecomposed organic matter (fibric)

	i	occurrence of permafrost
	p	ploughed
O horizon	b	buried
	d	litter layer
	f	fermentation layer
	h	humus layer
	i	occurrence of permafrost
A horizon	a	anthropic
	b	buried
	c	cultivated
	d	hard setting
	g	gleyic
	h	humic (humus enriched, uncultivated)
	i	gelic (occurrence of permafrost)
	k	calcic
	m	mollic
	n	sodic
	o	ochric
	p	plaggic
	r	rigolen, deep ploughing, c 1m.
	u	umbric
	v	vertic
	y	gypsic
	z	salic
E horizon	a	podzolic
	b	buried
	g	gleyic
	i	occurrence of permafrost (gelic)
	m	massive
	n	sodic
	p	pale brownish eluvial horizon typical of argillic brown earths
B horizon	b	buried
	c	accumulation of concretions
	g	gleyic
	h	humic
	i	gelic
	j	sulphidic (jarosite)
	k	calcic
	m	cemented, indurated
	n	sodic
	p	plinthic
	q	silicic
	r	strong reduction as a result of ground water influence
	s	sesquioxidic
	t	argillic

	v	vertic
	w	cambic
	x	fragic
	y	gypsic
	z	salic
C horizon	b	buried
	c	concretionary accumulation
	g	gleyic
	i	gelic
	j	sulphidic (jarosite)
	k	calcic
	m	cemented, indurated
	n	sodic
	p	plinthic
	q	silicic
	r	strong reduction as a result of groundwater influence
	s	sesquioxidic
	x	fragic
	y	gypsic
	z	salic
R horizon	r	intensely reduced
	u	uconsolidated, weathered material

Strategy No. 3 (Use of horizon attributes to determine designation)

This proposal has developed from the concept of diagnostic horizons; those horizons possessing attributes which may be quantitatively assessed. This approach breaks with tradition and in effect symbolises the defined attributes of the horizon - as used in the FAO-Unesco *Soil Map of the World* Revised legend (1988) and the proposals for an International Reference Base for soils. It focuses upon the results of the soil forming processes, but does not invoke the 'genetic' involvement of nebulous soil forming processes. The master horizons are retained with the same definitions as in the first two strategies. Essentially it is a combination of feature recognition and the diagnostic horizon concept.

H horizons	H_a	sapric material
	H_e	hemic material
	H_i	fibric material
O horizons	O_L	litter
	O_f	fermentation
	O_h	humus
A horizons	A_a	cultivated surface organo-mineral horizon

	A_d	hard setting organo-mineral horizon
	A_g	surface organo-mineral horizon with gleyic attributes
	A_k	surface organo-mineral horizon with calcic attributes
	A_m	surface organo-mineral horizon with mollic attributes
	A_o	surface organo-mineral horizon with ochric attributes
	A_p	surface organo-mineral horizon raised with plaggen
	A_r	mixed surface layer resulting from deep ploughing
	A_t	weakly organic, fine textured playa floor material
	A_u	surface organo-mineral horizon with umbric attributes
	A_w	disturbed organo-mineral horizon of dumped material
	A_y	weakly organic, stony desert pavement surface horizon
E horizons	E_a	subsurface mineral horizon with uncoated grains and no mottling of podzolized soils
	E_b	pale subsurface mineral horizon of unpodzolized soils
	E_d	hard-setting subsurface mineral horizon with uncoated mineral grains
	E_g	subsurface mineral horizon with uncoated grains and ferruginous mottling
	E_n	hard-setting subsurface mineral horizon associated with underlying sodic horizon
B horizons	B_a	with andic attributes
	B_c	with fluvic attributes
	B_d	with gelic attributes
	B_e	with nitic attributes
	B_f	with ferralic attributes
	B_g	with gleyic attributes
	B_h	with humic accumulation
	B_i	with lixic attributes
	B_j	with jarosite accumulation
	B_k	with calcic attributes
	B_n	with natric attributes
	B_o	with residual sesquioxides
	B_p	with kandic attributes
	B_q	with silica accumulation
	B_r	with strong reducing conditions
	B_s	with spodic attributes
	B_t	with argillic attributes
	B_u	with luvic attributes
	B_v	with vertic attributes
	B_w	with cambic attributes
	B_x	with fragic attributes
	B_y	with gypsic attributes
	B_z	with halic attributes
C horizons	C_a	with andic material
	C_c	with fluvic material
	C_g	with gleyic attributes
	C_j	with jarosite accumulation

C_k with calcic material
C_n with sodic material
C_p with plinthic material
C_r strongly reduced material
C_x with fragic material
C_y with gypsic material
C_z with halic material

This list has been compiled from the characters used in the key to major soil groupings proposed in a discussion document about the International Reference Base for soil classification. Clearly, it is advantageous if the characters used in the identification of soil horizons are the same or similar to those used as criteria for classification. As further definition of diagnostic or defined horizons takes place, as demonstrated by Sombroek (1984) for the argillic horizon, increasing numbers of letters will be required to designate the different subtypes. This could be accommodated in this system, although for practical reasons not all letter designations could be connotative of the morphology observed. Alternatively, the addition of a third letter to the symbol, could indicate immediately any combination of characters present eg. natro-argillic (B_{tn}), stagno-argillic (B_{tg}).
The use of the letter D has been suggested for reg soils where incorporation of organic matter is negligible and desert pavement is a dominant feature, a proposal which has received support from the ICOMID committee. The A_y symbol proposed in this document was intended to summarise the yermic features of surface crust, a thin platy horizon with vesicular pores, desert pavement, sand-filled shrinkage polygons and rounded, pitted sand grains with a matt surface (Blume *et al.*, 1987; Sombroek, 1987).

Strategy No. 4 (FitzPatrick's system)

An approach to soil horizons which merits further consideration is that of FitzPatrick, argued cogently in several books and papers (FitzPatrick, 1967, 1971, 1980, 1988). He uses soil horizons as a basic unit in the development of a system of soil classification. Although the approach is different from many current systems of classification, FitzPatrick's observations are very relevent in the present context.

Soil horizons may be distinguished by one or more criteria, and in his examples, FitzPatrick has chosen four: colour, clay content, total basic cations and cation exchange capacity. Using these criteria he has delimited conceptual volumes in (soil) space, each of which contains many horizons. His nomenclature is based on conceptual volumes within which a system of reference segments (idealised profile forms) has been determined with a limited number of intergrade segments between them. Each of the identified segments has its place in a spatial arrangement and a key is used to identify the appropriate horizon name using additional characteristics observed in the field. It is asserted by FitzPatrick that with the key and co-ordinate diagrams the inter-relationships of soil horizons may be seen more clearly.

Definition of the soil horizons identified by FitzPatrick is given in the publications mentioned previously. Each reference soil horizon has a name ending in -----on, usually a word already familiar to soil scientists. Thus, the material known otherwise as mull becomes mullon (Mu) or a clay-enriched horizon becomes an argillon (Ar). In terms of the conventional ABC horizons, FitzPatrick's reference horizons may be listed as follows:

Horizons	Approximate FAO equivalents
Surface organic horizons	
Amorphon (Ap)	Histic H
Fermenton (Fm)	Fermentation
Fibron (Fi)	Histic H
Litter (Lt)	Litter
Gyttjon (Gj)	Histic H
Humifon (Hf)	Humus
Hydromoron (Hy)	Hydromor
Pseudofibron (Pd)	Histic H
A horizons	
Agron (Ag)	cultivated A
Alkalon (Ak)	Saline horizon
Anmooron (Am)	Umbric A
Buron (Bu)	Mollic A
Chernon (Ch)	Mollic A
Chloron (Ci)	Saline horizon
Dermon (De)	Umbric A
Duron (Du)	Duripan
Gelon (Gn)	Umbric or Ochric A
Granulon (Gr)	Ochric A
Halon (Hl)	Saline horizon
Hamadon (Ha)	Desert pavement
Kastanon (Kt)	Mollic A
Kuron (Ku)	Umbric A
Luton (Lu)	Umbric A
Modon (Mo)	Mollic A
Mullon (Mu)	Mollic A
Nekron (Nk)	Umbric A
Plaggon (Pg)	Plaggen
Primon (Pr)	Ochric A
Seron (Sn)	Ochric A
Sulphon (Su)	Saline horizon
Tannon (Ta)	Ochric A

E horizons

Candon (Co)	Albic E
Luvon (Lu)	Albic E
Minon (Mi)	Albic E
Zolon (Zo)	Albic E

B horizons

Alton (At)	Cambic B
Andon (An)	Cambic B
Arenon (Ae)	Cambic B
Argillon (Ar)	Argillic B
Calcon (Ck)	Calcic
Cerulon (Cu)	Cambic B
Cumulon (Cm)	Cambic B
Ferron (Fr)	Spodic B
Flavon (Fv)	Cambic B
Gleyson (Gl)	Cambic B
Glosson (Gs)	Cambic B
Gypson (Gy)	Gypsic
Helvon (He)	Cambic B
Hudepon (Hu)	Spodic B
Husesquon (Hs)	Spodic B
Jaron (Ja)	Sulfuric horizon
Krasnon (Ks)	Oxic B
Marblon (Mb)	Cambic B
Pellon (Pe)	Cambic B
Pesson (Ps)	Cambic B
Placon (Pk)	thin iron pan
Planon (Pn)	Argillic B
Rosson (Ro)	Cambic B
Rubon (Ru)	Cambic B
Rufon (Rf)	Cambic B
Sesquon (Sq)	Spodic B
Sienon (Si)	Cambic B
Solon (Sl)	Natric B
Sombron (So)	Humic B
Thion (To)	Sulfuric horizon
Verton Ve)	Vertic B
Veson (Vs)	Plinthite
Zhelton (Zh)	Oxic B

C horizons

Cryon (Cy)	Permafrost
Flambon (Fb)	Plinthite
Fragon (Fg)	Fragipan
Gluton (Gt)	Ironstone
Ison (Is)	Fragipan
Limon (Lm)	Lake Marl
Lithon (Lh)	Shattered rock
Oron (Or)	Ironstone

Pallon (Pl)	Gleying
Petron (Pt)	Shattered rock
Sapron (Sa)	Saprolite
Sideron (Sd)	Siderite

For full definition of these horizons refer to FitzPatrick (1980). Additionally, FitzPatrick proposes a notation for the designation of the parent material type. (In the following examples, AK refers to an acid coarse grained parent material and AS to an acid sand).

A useful method of notation for soil horizons was first put by forward by Sokolovsky (1932) and independently adopted by FitzPatrick. This involves using the horizon symbol in conjunction with the thickness of the horizon in a similar manner to a chemical formula:

$$Lt_2\ Fm_2\ Gn_4\ Mb_{20}\ Fg_{20}AK$$
$$Lt_2\ Fm_3\ Hf_2\ Mo_{10}\ Zo_{10}\ Sq_{25}\ In_{20}\ AS$$

This gives an improved impression of the nature and depth of the horizons present, for each horizon by definition possesses specific characteristics and could be applied to other systems of soil horizon designation.

Strategy No. 5 (Prescriptive horizons)

From the present study it has become apparent that over the past ten years a new trend in soil horizon designation has developed. In many ways this picks out the best points of former systems and has much to commend it. It retains the established concepts of the ABC master horizons but combines with them a tighter definition of subscript letters. It differs from the others in that the use of letter combinations is prescribed for horizons with specific morphological characteristics. In this system, the field pedologist is not given as much latitude in the use of horizon designations as in the past.

It is difficult to pin-point the exact beginning of the present trend, but the Canadian Soil Survey Committee (1978) seem to be the first to have a fully published account using this approach. It was followed rapidly by the Soil Survey of England and Wales (Avery, 1980) and by the New Zealand Soil Bureau (Clayden and Hewitt, 1986). Concurrently with this report, the Association Français pour l'Etude du Sol (1987) has produced a *Référentiel Pédologique Français*, (Première Proposition, Juillet 1987, Deuxième Proposition, Novembre 1988) in which it is clear that French pedologists have sympathy for this approach and appear to be developing along similar lines. To illustrate the approach used by these countries examples are given from Canada, UK and France:

Canada

A - This is a mineral horizon formed at or near the surface in the zone of leaching or eluviation of materials in solution or suspension, or of maximum *in situ* accumulation of organic matter or both. The accumulation of organic matter is usually expressed morphologically by a darkening of the surface soil (Ah), and conversely the removal of organic matter is usually expressed by a lightening of the soil color usually in the upper part of the solum (Ae). The removal of clay from the upper part of the solum (Ae) is expressed by a coarser soil texture relative to the underlying subsoil layers. The removal of iron is indicated usually by a paler or less red soil colour in the upper part of the solum (Ae) relative to the lower part of the subsoil.

Ah - A horizon enriched with organic matter. It is used with A alone (Ah), or with A and e (Ahe), or with B alone (Bh), or with B and f (Bhf).

England and Wales

E - Subsurface mineral horizon that contains less organic matter and/or dithionite-extractable iron and/or silicate clay than the immediately underlying horizon, presumably as a result of removal of one or more of these constituents. The moist colour value is 4 or more, the dry colour value 5 or more, or both. An E horizon is differentiated from an overlying A or organic horizon by higher colour value and smaller organic matter content, and from an underlying B by higher colour value (especially when dry), lower chroma, smaller clay content, weakly developed structure, or normally, some combination of these. It consists mostly of uncoated sand or silt grains, or has an asepic or insepic plasmic fabric with few or no strongly oriented clay bodies.

Ea - E horizon without ferruginous mottles or nodules, in which coats on sand and silt particles are absent, very thin or discontinuous, so that the colour of the horizon is mainly determined by the colours of the uncoated grains. It usually overlies a Bh horizon, but can also overlie a Bt horizon.

France

Les Horizons B

Horizons minéraux ou organo-minéraux à structuration pédologique généralisée, caractérisés par une accumulation de matière par rapport aux horizons A, E et C. Un horizon A ou E est généralement présent dans le solum, mais il peut avoir été érodé et ne plus exister. Dans les horizons B il y a un enrichissement absolu qui peut être dû:

- uniquement à des apports en provenance d'autres horizons superposés verticalement ou juxtaposés latéralement (apports illuviaux)
- ou à la combinaison d'apports illuviaux et de transformation sur place de minéraux pré-existants.

Horizon B Textural = BT

Horizon qui contient des argiles phylliteuses illuviales, formé en relation avec un horizon éluvial E lequel se trouve au-dessus de lui ou en amont. Le BT peut se trouver en surface si le solum a été partiellement tronqué. Il présente les caractères suivants:

- une teneur en argile supérieure à celle des horizons A, E, S ou C qui sont présents dans le même solum.
- une épaisseur d'au moins 15 cm. S'il est composé entièrement de "bandes", leur épaisseur doit être égale ou supérieure à 1 cm et atteindre, au total, 15 cm.
- dans les sols à structure particulaire l'horizon BT doit présenter des argiles orientées reliant les grains de sables entre eux et décelables également dans certains pores.
- lorsqu'il existe des agrégats (cubes, polyèdres, prismes), présence de nombreux revêtements argileux sur certaines surfaces: faces d'agrégats horizontales et verticales, chenaux, canalicules. Une observation microscopique est souvent nécessaire. Il s'agit de matières essentiellement argileuses et ferriques, généralement bien orientées par rapport aux parois et dont la nature et l'organisation contrastent par rapport à la matrice.

These horizon definitions are tightly tied to specific horizon designations which are only possible to prescribe when the soils of an area and all the possible combinations of horizon characters are known. Such an approach may be possible in countries where extensive and detailed soil surveys have taken place, but may not be so appropriate in countries where there is incomplete knowledge of the soils.

CONCLUSIONS

Inevitably the conclusions which follow are of a personal nature, but they have been arrived at following a study of the existing systems of soil horizon designation. A working paper was circulated to the organisations mentioned in Chapter 5 and to a number of individual soil scientists. Comments were also requested in the Bulletin of the International Society of Soil Science. The comments made by various correspondents have been carefully considered and incorporated into this monograph. The following points appear to be significant when considering future development and use of horizon designations.

1. Horizon designations fulfil a useful function in the labelling of soil horizons and facilitate discussion about them and their characteristics. This is helpful in both theoretical and practical aspects of soil science. Moreover, there is general agreement among pedologists about the significance of soil horizons.
2. Any further development should attempt to maintain simplicity which enables the use of soil horizon designations in the field and yet the system should be capable of subsequently incorporating the results of laboratory determinations where these are required for closer identification purposes and publication.
   There is the possibility of having a two-level symbolisation; a simple designation for field and general use (e.g. Strategy No. 1) and a more complex designation for specialist and classification use (e.g. Strategy No. 5) in scientific publications.
3. The concept of A, B and C master horizons is well established and there seems little advantage of attempting to replace them with other symbols, for example upper (U), middle (M) and lower (L), to indicate the position of the soil horizon within the profile. Should a change be thought desirable, (perhaps to latin indices?) the advantage would be to shift away from the implied logic that A is followed by B which in turn is followed by C. However, since inclusion of the E horizon in many designation systems, this rather facile assumption is less likely.
4. It would seem sensible, and helpful, for the future use of soil horizon designations if further rationalisation took place amongst the lower case subscript letters which are employed in association with the master horizon symbols. Two possible ways forward are contained in strategies 1 and 2. Both continue to use symbols in common use throughout many countries in the world. It has been suggested that two lower case symbols could be used, signifying perhaps major and minor characteristics, or emphasising the degree of development by repeating the symbol.
5. As descriptive terminology and classification criteria have been quantified and almost become identical, it is possible to use use various attributes collectively to identify a soil horizon as well as use them for classification purposes. Such a development would be useful, as existing soil horizon designation systems do not

always relate easily with systems of classification. Strategy 3 is an attempt to overcome this problem, and as it has been put forward using the IRB attributes as a guide, it has received positive support.

6. An alternative approach to the identification and use of soil horizons in soil classification has been proposed by FitzPatrick (1980, 1988a). In his system, soil characteristics are used to define reference soil horizons which are employed both in soil profile identification and in a classification system which is based on the horizons present, not the profile itself. The horizons, which are the basis of FitzPatrick's system, form conceptual segments in space and may be delimited by a co-ordinate system of nomenclature and symbols. This system is summarised in strategy 4 and received support at the ISSS Conference in Rennes.
7. A number of soil survey organisations have already begun to use soil horizon designations based on the A, B, C master horizons but with more closely prescribed characteristics. These seem to be a blend of the diagnostic horizon from *Soil Taxonomy* (Soil Survey Staff, 1975) and the morphological (not genetic) assessment of the features of soil horizons employed by many organisations concerned with soil survey. Examples of definitions of these tightly defined horizons are given in Strategy 5, which appear to indicate the trend of official thought in some National Soil Survey organisations.
8. The use of a soil profile formula, as suggested by Sokolovsky and FitzPatrick is commended but it has been suggested also that it should be possible to include additional information about the nature of the horizon boundaries by additional signs between each of the above horizon symbols. The terms given (p. 13) for distinctness of boundary perhaps could be represented:

   abrupt !, clear I, gradual /, diffuse *

   In circumstances where features are increasing or decreasing in amount between successive horizons, such as the clay content or the content of calcium carbonate, it is possible to use the < or > symbols between the horizon designation symbols, or if it was required to emphasise a large increase, the symbols could be << or >>.

These conclusions may be summarised by stressing the usefulness of some form of horizon designation for use in interpretation, discussion and communication. The system should be simple and usable in field and laboratory as well as for publication purposes. If an International Reference Base for soils is to be adopted then some form of designation based upon the attributes of soil horizons would seem necessary.

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APPENDIX

LIST OF SOIL HORIZON DESIGNATION SCHEMES HELD IN ISRIC LIBRARY

The following soil horizon designation schemes and relevant papers have been gathered and are held in the library at ISRIC. They accompany a study of the origin and development of soil horizon designations undertaken in 1987 which is recorded in Working Paper and Preprint 87/03 and the Selected Bibliography on Soil Horizon Designations, Working Paper and Preprint 87/04. Listing is by country of origin, but many of the schemes have been developed for more extensive application. The papers may be consulted in the library at ISRIC or copies of papers may be made available on payment of a fee to cover reproduction and postage.

Australia	Northcote, 1979 McDonald *et al.*, 1984
Austria	Fink, 1969 Krabichler, 1984
Brazil	EMBRAPA, 1981 EMBRAPA, 1988
Cameroon	Garaud *et al.*, 1976
Canada	Soil Survey Committee, 1978 Klinka *et al.*, 1981 1987 (Revision of SSCS, 1978) Valentine, 1987
Czechoslovakia	Hrasko *et al.*, 1987
Ecuador	Posso G. del M., 1974
FAO	Soil Map of the World, Vol.1, Legend, Unesco, 1974 Guidelines for Soil Profile Description, 1977 Guidelines for Coding Soil Data, 1986 Soil Map of the World, Revised Legend, 1988
France	Maignien, 1980 Boulaine, 1984 Working Group, 1985

	AFES, 1987
	AFES, 1988
	Girard, 1989
	Lahmar, Aurousseau and Bresson, 1989
Germany (FRG)	Kubiena, 1953
	Zinecker, 1955
	Schaufelberger, 1959
	Blume, 1965
	Scheffer and Schachtschabel, 1966
	Glatzel *et al.*, 1967
	Mückenhausen, 1975
	Blume and Schlichting, 1976
	DIN, 1982
	Working Group, 1985
Germany (GDR)	Reuter, 1953
	Ehwald, 1957
Hungary	Szabolcs, 1966
Italy	Sanesi, 1977
Japan	Otowa, 1967
	Kawaguchi and Kyuma, 1969
	Matsui, 1982
Netherlands	Mohr, 1944
	de Bakker and Schelling, 1966
	Bos and Sevink, 1975
	Bal, 1982
	de Bakker, 1987
New Zealand	Taylor and Pohlen, 1962
	Clayden and Hewitt, 1985
	Clayden and Hewitt, 1986
	Clayden and Hewitt, 1989
Poland	Krolikovski *et al*, 1986
Republic of South Africa	MacVicar *et al*, 1977
Romania	Research Institute, 1979

Spain	Ojea and Fernandez, 1982
Switzerland	Frei, 1975 Working Group, 1979
United Kingdom	Avery, 1964 FitzPatrick, 1967 Muir, 1969 Clarke and Beckett, 1971 Hodgson, 1974 Avery, 1980 Landon, 1984 FitzPatrick, 1987 Working Group, 1987
USA	Shaw, 1928 Smith and Harland, 1928 Heiberg and Chandler, 1941 Soil Survey Staff, 1951 Ruhe and Daniels, 1958 Whiteside, 1959 Whiteside, 1960 Soil Survey Staff, 1962 Wilde, 1965 Wilde, 1970 Soil Survey Staff, 1975 Soil Survey Staff, 1981 Guthrie and Witty, 1982 Soil Management Support Services, 1983 National Soils Handbook, 1983 Soil Management Support Services, 1986
USSR	Sokolovsky, 1930 Zakharov, 1930 Tiurin *et al,* 1959 Kovda, 1973 Glazovskaya, 1983
Zambia	Tijmons (no date)

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